Corresponding Excel files have been provided for reference if any field is unreadable in PDF

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
20215	0	0	0	0	It would be good to have more discussion on COVID, see also - Le Quéré, C., Peters, G. P., Friedlingstein, P., Andrew, R. M., Canadell, J. G., Davis, S. J., ... & Jones, M. W. (2021). Fossil CO 2 emissions in the post-COVID-19 era. Nature Climate Change, 11(3), 197-199. - Le Quéré, C., Jackson, R. B., Jones, M. W., Smith, A. J., Abernethy, S., Andrew, R. M., ... & Peters, G. P. (2020). Temporary reduction in daily global CO 2 emissions during the COVID-19 forced confinement. Nature Climate Change, 10(7), 647-653.	Noted. We have chosen not to focus on COVID in this chapter due to limited literature on its impliations.	Nikas Alexandros	National Technical University of Athens	Greece
45879	0	0	0	0	Section with knowledge gaps is missing. We urge the authors kindly to add this important information. Please see our comment on the Entire Report regarding knowledge gaps.	Noted. We have not included a section on knowledge gaps but have rather tnoted throughout the chapter where uncertainty prevails and therefore where new knowledge woudl be useful.	Government of Germany	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety International Climate Policy	Germany
64597	0	0	0	0	Many (typing and spelling) errors: the whole chapter needs a careful editing check.	Taken into Account	Government of Netherlands	Ministry of Economic Affairs and Climate Policy	Netherlands
85769	0	0	0	0	It may be beneficial to include more content on hydrogen. For example, there is an Australian Hydrogen roadmap that provides a blueprint for the development of a hydrogen industry in Australia (https://www.csiro.au/en/Do-business/Futures/Reports/Energy-and-Resources/Hydrogen-Roadmap) and Europe is funding large increase for hydrogen development. It may also be beneficial to include more content on accelerating technology development through investment and incentives frameworks for low emissions technologies. For example, Australia's Technology Investment Roadmap will accelerate development and commercialisation of new and emerging low emissions technologies. It facilitates this by defining the priority technologies to guide Government investment, setting targets for technology costs that would make them cost-competitive with high emission incumbents, and identifying deployment pathways to achieve these targets. https://www.industry.gov.au/sites/default/files/September%202020/document/first-low-emissions-technology-statement-2020.pdf	Taken into Account. We have extensive discussion of hydrogen	Government of Australia	Department of Industry, Science, Energy and Resources	Australia
85771	0	0	0	0	It may be beneficial to include more content on geothermal.	Rejected: Space constraints limit what we can say about any technology	Government of Australia	Department of Industry, Science, Energy and Resources	Australia
85773	0	0	0	0	It may be beneficial to include more content on wave power. There is brief mention in section 6.4.2.9. Carnegie (based in Fremantle, Australia) has been developing the CETO system.	Rejected: Space constraints limit what we can say about any technology	Government of Australia	Department of Industry, Science, Energy and Resources	Australia
19863	0				A discussion of the role of international carbon market mechanisms (CDM, JI) for the energy sector, particularly renewable energy should be added (possibly in section 6.3.5)	Noted. Space constraints limit the discussions of every individual policy.	Axel Michaelowa	University of Zurich	Switzerland
20285	0				Excellent updated synthesis of the current state of the topic. Only too long, would be good to synthetize.	Noted. We are roughly at the prescribed length	Avelino G. Suarez	Research Centre for the World Economy	Cuba

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
21081	0				The Marine Renewable Energies (MRE) theme seems to be very little developed throughout the chapter, although it is said in 6.4.2.9 (Marine Energy) that it may represent a real opportunity if developed: The oceans are a vast source of energy (Hoegh-Guldberg et al. 2019) and an emerging alternative to fossil fuels. The research could appear disproportional between offshore wind energy and the other MREs.	Rejected: Space constraints limit what we can say about any technology	Government of France	Ministère de la Transition écologique et solidaire	France
21083	0				Please consider this proposition, if relevant and applicable: it could be useful to provide a scenario for a 100% transition towards renewables, with a complete downturn on fossil fuels. If documented quantitatively, reporting the elements on the deployment of renewable could be an important point of comparison with the current projections for the near and long term future.	Taken into Account. We have a special box on net-zero energy systems.	Government of France	Ministère de la Transition écologique et solidaire	France
21085	0				With regards to investments in the transmission network, this chapter seems to have a stronger focus on the optimistic perspective where flexible demand will alleviate demand for reinforcement. The need for investment might however precede the deployment of equipment in renewables, allowing dispatching demand intertemporarilly. Otherwise, it could mean that the pace at which we can replace fossil plants would be constrained by the transmission network on the short run.	Noted. We comment frequently throughout the chapter on the need for these flexibility requiremens to be able to incorporate VRE technologies.	Government of France	Ministère de la Transition écologique et solidaire	France
21087	0				The instability of hydrocarbon prices since the middle of the decade, further reinforced by the health crisis, is contributing to a sharp reduction in upstream oil investments. Contrary to what is currently observed, it is not impossible that the price of oil will rise in the medium term and that, as the analysis of the International Energy Agency shows, a phenomenon of "missing barrels" to cover demand will become structuring. The chapter could probably include a more detailed analysis of different oil (and gas) price scenarios and the sensitivity of competing sectors, which is not the case. This is a paradox, as the effect of carbon prices (6.3.8 p. 21-22, 6.7.5 p. 119) and fossil fuel subsidies (Box 6.3. p. 22) is more widely considered. In this perspective, one additional box could be included to discuss the sensitivity of the deployment of low-carbon energies to different profiles of hydrocarbon price evolution over the next decade (with also a reflection in terms of stress tests, and in case of oil price shock)	Rejected: This topic is more appropriate for Chapter 4	Government of France	Ministère de la Transition écologique et solidaire	France
21089	0				One subject that is worth further developing is related to the uncertainties in energy demand. The major trends are quickly addressed in 6.3.2 (p.6.13, 6.14), as well as the demand response (6.4.6 p.6.65) to contribute to the need for flexibility and the effects of climate change on consumption (6.5.2 p.6.75) - as well as, moreover, in Chapter 5, "Demand, services and social aspects of mitigation", but without direct influence on the analyses in Chapter 6. However, it imports to integrate the different factors which are likely to influence the demand for fossil fuels, so as to better understand the investment strategies in the upstream sectors (oil, coal and gas) and the consequences on the prices in these sectors (and the resulting effects on the competitiveness of renewables). Therefore, section 6.7.4 (Fossil fuels in transition, p.6.116-117) takes an insufficient discussion of the possible evolutions in the field of fossil energies, especially of the production evolution scenarios taken as a reference (p.6.116) and essentially analysed by looking at production levels compatible with the objectives of the Paris Agreement (from a perspective similar to that of the UNEP gap report) and by discussing the prospects of the CCS and the possibilities of substitution in the various sectors, particularly transport (p.6.117).	Noted. We do not understand this comment.	Government of France	Ministère de la Transition écologique et solidaire	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
21091	0				A focus worth considering is on the "net zero" strategies of companies ((cf. the three European majors, BP, Shell and Total, which have announced carbon neutrality in 2050). For example, investments in renewable energies and intra-sectoral competition could influence the pace of development of low-carbon technologies. This perspective could enrich section 6.6 in that sense.	Noted. We have taken more a national perspective on actions, although we mention the roles of actor throughout the energy system	Government of France	Ministère de la Transition écologique et solidaire	France
21093	0				section 6.7.5 Policy and Governance (p.6.117-6.119) does not seem to “capture” various recent developments in public policy discussions, whose importance cannot be overlooked: the return to the Paris Agreement of the United States, the European objectives for 2030 in the framework of the Green Deal, the Chinese commitment to carbon neutrality in 2060, etc. All of these elements are likely to have an influence on the energy transition. Hydrogen, for example, is present in several recovery plans.	Noted. Revised version includes examples of actual policy implementations and discusses policy mixes (not just targets).	Government of France	Ministère de la Transition écologique et solidaire	France
21095	0				Please consider including a deeper analysis of what the "post-Covid" macro-economy could be (and in particular the level of interest rates), with different influences, notably on section 6.7.5 Policy and Governance (p.6.117-6.119)	Noted. We have chosen not to focus on COVID in this chapter due to limited literature on its impliations.	Government of France	Ministère de la Transition écologique et solidaire	France
28649	0		0		The IEA has produced two very relevant and influential reports on emissions reductions from the energy system to achieve net zero scenarios but these are not mentioned anywhere, some content seems counter to the IEA modelling for energy technologies even. IEA Energy Technology Perspectives 2020 should be read by all authors, and IEA Special Report on CCUS (2020) by those covering CCUS aspects.	Noted. We have chosen to focus more prominently on peer-reviewed literature in the text. That said, we have read the various reports published on CCUS by IEA.	Tim Dixon	IEAGHG	United Kingdom (of Great Britain and Northern Ireland)
31071	0				A cogent treatment of deep well geothermal is missing from Chapter 6: Energy Systems. This is significant, since the oil/gas sector could be hired to develop deep well geothermal wells and reservoirs on a very large scale, and that would provide a profit motive to encourage them to leave their current oil/gas assets in the ground, and transition to green energy. Moreover, the idea that the developed nations would fund the transition ought to have some profit built in to the negotiations for them to be successful. Deep well geothermal does not need native hydrological resources, but instead uses a closed loop system for heat transfer, and can be done in every country. The MIT study on the subject shows enough deep well energy resources to power civilization for several millennia. Including a cogent treatment would improve the chapter.	Accepted The prospects for harnessing the geothermal potential in a large number of countries include deep geothermal technology. However the costs remain particularly high (https://www.r-e-a.net/technologies/deep-geothermal). It is therefore very likely that this option will remain marginal in the next couple of decades	Daniel Helman	College of Micronesia-FSM	Micronesia, Federated States of
31077	0				A detailed treatment of nuclear energy is missing from Chapter 6: Energy Systems. This ought to include information about the current plans of about 30 new nations to develop new nuclear power programs, thereby doubling the number of countries with nuclear power programs. The text ought also to include the risk of nuclear arms proliferation as new countries develop the technology. Some will be dishonest actors, looking to develop arms instead of energy. A pathway for the safest development of nuclear energy by these nations ought to be explicitly laid out and a new treaty ought to be promoted, banning the use of any experimental or research reactors by these new countries, and instead mandating small modular reactors. New protocols related to materials enrichment facilities also ought to be adopted. Note that Saudi Arabia is now developing nuclear materials enrichment, and whether this is strictly for its new nuclear power program remains to be seen. Likewise, Russia’s new floating nuclear power plants like the Akademik Lomonosov ought to be included, as these may be hired out to other nations. There is a hazard from tsunami, e.g. even in the Arctic, as the permafrost thaws, submarine debris flows which cause tsunamis will be more common.	Rejected. We have a full section on nuclear energy iSecton 6.4	Daniel Helman	College of Micronesia-FSM	Micronesia, Federated States of

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
31101	0				Chapter 6 is weak in presenting a coherent transition for the transit sector in the nearterm. There ought to be a special section that presents a viable two year transition plan to zero anthropogenic carbon release, with several alternatives. It is unreasonable for the authors to assume that governments will be able to put this together themselves without a roadmap.	Transportation transitions are addressed in Chapter 10; near-term transitions are addressed most directly in Chapter 4.	Daniel Helman	College of Micronesia-FSM	Micronesia, Federated States of
31443	0				It is very important for us as SIDS to make sure that the WGIII assessment accounts not only for global developments but also highlights regional challenges that may differ from the larger scale picture. For example, the global reduction in RE costs have to be put into regional perspectives that would help to clarify that there are still considerable challenges that need to be overcome in terms of energy system transformation. Remote islands in the Pacific won't necessarily immediately see the cheaper costs due to supply challenges etc. It would help a great deal if specific challenges for most vulnerable countries are assessed in greater detail and elevated more to the ES. Case-study like examples would make it easier to compare different regional circumstances and assess specific hurdles that have to be overcome.	Noted. We have tried to include as much information as we could within the constraint of the IPCC. We have included regional information when assessing technology potentials, when looking at history, and when looking at future transitions. However, we cannot work on individual countries in the context of this report for space and other reasons.	Government of Palau	Government	Palau
43745	0				Heartfelt thanks to the author team for compiling a large amount of valuable information in this chapter. We appreciate the insights on developments since the AR5. In general, a more region-specific assessment would be appreciated.	Noted. We have tried to include as much information as we could within the constraint of the IPCC. We have included regional information when assessing technology potentials, when looking at history, and when looking at future transitions. However, we cannot work on individual countries in the context of this report for space and other reasons.	Government of Jamaica	Meteorological Service Division	Jamaica
47175	0				There are no references to SIDS with respect of potential dangers of investment in new fossil infrastructure (e.g. oil-to LNG (liquified natural gas) switch)	Noted. We cover the issues of new fossil infrastructure throughout the chapter.	Stuart Minchin	The Pacific Community	Australia
47177	0				Retrofit of fossil-fuel based power plants with Carbon Capture and Storage is uncertain.	Noted. CCUS retrofit is established as viable but costly. This is discussed in Section 6.4.	Stuart Minchin	The Pacific Community	Australia
47445	0				For SIDS, some of the positive global developments regarding, for example, more competitive RE costs, cannot be harvested easily due to geographical constraints. If possible, please include a case-study-like section that highlights regional differences in potential to adopt new technologies. It is very important to further highlight the challenges faced by the most vulnerable countries, like SIDS, in this regard.	Noted. We have tried to include as much information as we could within the constraint of the IPCC. We have included regional information when assessing technology potentials, when looking at history, and when looking at future transitions. However, we cannot work on individual countries in the context of this report for space and other reasons.	Government of Saint Lucia	Department of Sustainable Development - Ministry of Education, Innovation, Gender Relations and Sustainable Developement	Saint Lucia
50183	0				We would like to thank authors for a highly informative SOD of this chapter. Information on developments relevant to energy system transformations are very well displayed and highly appreciated. We recommend to complement this evaluation by region-specific assessments to enable policy makers to make better use of the information provided. SIDS face particular challenges in energy system transformation, such as grid stability challenges at high renewable shares. Specific insights on these regional challenges would be very useful.	Noted. We have tried to include as much information as we could within the constraint of the IPCC. We have included regional information when assessing technology potentials, when looking at history, and when looking at future transitions. However, we cannot work on individual countries in the context of this report for space and other reasons.	Anna Main	Ministry of Foreign Affairs and Trade	Samoa
50185	0				For SIDS, information on the side effects of decentralized and renewable-based energy systems would be of high relevance. It would be particularly interesting to assess the impact of renewable energy systems in terms of security of supply and resilience to climate change and extreme weather events.	Taken into Account. We now have a short box on system resilience.	Anna Main	Ministry of Foreign Affairs and Trade	Samoa

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
61741	0				The chapter refers to "renewable energy" throughout in regards to climate mitigation, even though it would be much more accurate and scientifically correct to use "low carbon". Renewable energy includes unsustainable and problematic – even high climate impact – energy sources while it also excludes one of our most potential low-carbon energy source nuclear energy. See more on the problems of the term "Renewable energy" and why "low carbon" should be used instead from Harjanne and Korhonen, 2018, https://doi.org/10.1016/j.enpol.2018.12.029	Rejected. The definition of renewable energy sources is sufficiently well established as to be clear that it does not include nuclear. We do include nuclear within the category of low-carbon technologies.	Rauli Partanen	Think Atom	Finland
66173	0				In view of a balanced assessment text, we ask the authors to consider assessing also the following articles and report for inclusion in the text. 1) Schneider et al. World Nuclear Industry Status Report 2) Verbruggen, et al. (2014) Assessment of the actual sustainability of nuclear fission power. Renewable and Sustainable Energy Reviews 3) Stirling, A. (2014) Transforming power: Social science and the politics of energy choices. Energy Research and Social Science 4) Gillinsky, V. (2020) The US government insurance scheme for nuclear power plant accidents no longer makes sense. Bulletin of Atomic Scientists	Noted. Thank you for these references. We are including references as deemed appropriate to support the synthesis in this chapter.	Government of Belgium	Belgian Federal Science Policy (BELSPO)	Belgium
75007	0				Consider adding regional disaggregation to the chapter as opposed to large grouping	Noted. We have tried to include as much information as we could within the constraint of the IPCC. We have included regional information when assessing technology potentials, when looking at history, and when looking at future transitions. However, we cannot work on individual countries in the context of this report for space and other reasons.	Government of Kenya	Kenya Meteorological Service	Kenya
75743	0				Although elements of characterisation for mitigation options are given in section 6.4.1 in Table 6.1 throughout rest of the section, the metrics defined in table 6.1 is not addressed for all the options. The approach lacks uniformity. The details are given in proceeding comments. Also, why not quantify the metrics in Table 6.1 and introduce some sort of grades on whether the particular option meets the metric's criteria. As a result, table 6.9 looks like a subjetive grade made by authors instead of objective grade defined by data (references).	Noted. Due to space constraints, we were not able to go through every metric in every section.	Krešimir Trontl	University of Zagreb, Faculty of Electrical Engineering and Computing	Croatia
80997	0				Chapter 6 describes the energy technologies for production, transport, storage and end use conversion. Although many adequate technology assessments are in this chapter, the technology assessments for hydrogen production, transport, storage and end use conversion are not up to date, sometimes misleading or not true and subjective. In above comments I have tried to picture the main development in hydrogen technology, but let I highlight three issues in the comments below	Taken into account.. We have updated the hydrogen material.	Ad van Wijk	TU Delft	Netherlands
81879	0				We would like to thank authors for a highly informative SOD of this chapter. Information on developments relevant to energy system transformations are very well displayed and highly appreciated. We recommend to complement this evaluation by region-specific assessments to enable policy makers to make better use of the information provided. SIDS face particular challenges in energy system transformation, such as grid stability challenges at high renewable shares. Specific insights on these regional challenges would be very useful.	Noted. We have tried to include as much information as we could within the constraint of the IPCC. We have included regional information when assessing technology potentials, when looking at history, and when looking at future transitions. However, we cannot work on individual countries in the context of this report for space and other reasons.	Francella Strickland	Ministry of Foreign Affairs and Trade	Samoa
81881	0				For SIDS, information on the side effects of decentralized and renewable-based energy systems would be of high relevance. It would be particularly interesting to assess the impact of renewable energy systems in terms of security of supply and resilience to climate change and extreme weather events.	Noted. We have included a box that highlights the questions around security of supply , even if it doesn't supply answers.	Francella Strickland	Ministry of Foreign Affairs and Trade	Samoa

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
84097	0				To my considerable regret I havent managed to read the chapter as I would have wished and imagine others have reviewed the technology and systems side of the work. So just a few brief, diverse comments, apologies drawn mostly from my own research in field.	Noted. We are disappointed that you have not been able to read the chapter.	Michael Grubb	UCL - Institute of Sustainable Resources	United Kingdom (of Great Britain and Northern Ireland)
84099	0				Innovation in energy is crucially important and I think it now well established that it arises from a wide range of forces, but with an improtant role for demand-pull. A Systematic Review intended to help inform the IPCC on the topic conducted a formalized search, with a 15 person international teams, screening down to identify and assess 227 original papers on the topic, which may be useful to consider: Grubb M., P.Drummond, A.Poncia, W.McDowall, D. Popp, S.Samadi, C.Penasco, K.Gillingham, S.Smulders, M. Glachant, G.Pavan, G.Hassel, E.Mizuno, E.Rubin, A. Dechezlepraitre (2021). Induced innovation in energy technologies and systems a review of evidence and potential implications for CO2 mitigation, Environ. Res. Lett. https://doi.org/10.1088/1748-9326/abde07	Noted. Innovation processes are handled in another chapter of this report.	Michael Grubb	UCL - Institute of Sustainable Resources	United Kingdom (of Great Britain and Northern Ireland)
84101	0				One thing that is really important but I think inadequately understood is determinants of technology growth rates. Chapter 2 has some good review work on this. The following is only published as a report, but underlined the imporance of the question and suggested to me that, given all that has happened in renewables and EVs, a lot of energy projections may be not much more than guesswork about how much exponential growth wil continue - but the impacts could be dramatic within a decade: Grubb, M., Drummond, P. and Hughes, N. (2020) The Shape and Pace of Change in the Electricity Transition: Sectoral dynamics and indicators of progress. Available at: https://www.wemeanbusinesscoalition.org/wp-content/uploads/2020/10/Shape-and-Pace-of-Change-in-the-Electricity-Transition-1.pdf (Accessed: 14 October 2020).	Noted. Innovation processes are handled in another chapter of this report.	Michael Grubb	UCL - Institute of Sustainable Resources	United Kingdom (of Great Britain and Northern Ireland)
84103	0				The role of finance in energy transitions	Noted. We discuss this when we discuss investments, but a more thorough treatment can be found in another chapter of this assessment.	Michael Grubb	UCL - Institute of Sustainable Resources	United Kingdom (of Great Britain and Northern Ireland)
84105	0				The role of finance in energy transitions is important but studies that combine theory and national empirics are limited. The role of finance structures in the UK energy transition is explored through a Three Domains framework, applied to financial actors, in Hall, S., T. J. Foxon, and R. Bolton, 2017: Investing in low-carbon transitions: energy finance as an adaptive market. Clim. Policy, 17, 280–298, https://doi.org/10.1080/14693062.2015.1094731.	Noted. We discuss this when we discuss investments, but a more thorough treatment can be found in another chapter of this assessment.	Michael Grubb	UCL - Institute of Sustainable Resources	United Kingdom (of Great Britain and Northern Ireland)
84107	0				Given the dramatic scale (and pace) of the UK electricity transition, I was surprised that this chapter seems to say so little about it. An analysis of the origins, evolution and impact of the UK's 2013 Electricity Market Reform, which was largely responsible, is available as Grubb M. and D.Newbery (2018), UK Electricity Market Reform and the Energy Transition: Emerging Lessons, Energy Journal, Vol. 39, No.6, DOI: 10.5547/01956574.39.6.mgru.	Noted. We did not, unfortunately, have space for a deep dive case study on the UK transition.	Michael Grubb	UCL - Institute of Sustainable Resources	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
84109	0				The selection of case studies in the Technical Summary seems not to cover actual empirics of major sectoral emission reductions. There are already elements of the UK energy transition in Chapters 2 and 13, but Chapter 6 would seem the natural home for a more integrated explanation of how the UK more than halved power sector emissions. Should the authors wish, I reiterate my offer to try and pull a few paragraphs together or suggest others who could.	Noted. We did not, unfortunately, have space for a deep dive case study on the UK transition.	Michael Grubb	UCL - Institute of Sustainable Resources	United Kingdom (of Great Britain and Northern Ireland)
14891	1	1			There were three major developments in terms of technological deployment and awareness in strategies since AR5: a) cheap and rapidly growing intermittent RE and batteries; b) sectoral coupling (road transport electrification, heat pumps, PtX, etc.); and c) awareness of the opportunity to reduce primary energy demand and associated GHG emissions with better service provisioning systems that simultanously lead to equitable outcomes in wellbeing. While all issues are mentioned, especially b) sector coupling is shortlined (6.4.3 is a good and valuable starting point), especially in terms of high-level messages. Only few models deal with these issues explicitly and chapter 3 only points to electrification on the side, while spending pages after pages on potentially unsustainable high level of bioenergy deployment. This seems to represent more the content of models than the overall level of insights of what works and what doesn't. Energy system model with high resolution in sector coupling are existing but not represented (e.g. in chapter 3, chapter 6 cites some studies). Most importantly, the combination of the 3 strategies remains unconsidered: very aggressive RE/battery deployment, rapid sector coupling, and building better service provisioning systems (the current US minister of transport seems to be ahead of the curve here). Importantly, while also very rapid deployment of intermittent RE is likely to be insufficient to meet rising demand for Primary Energy in 2050, it may meet demand if combined with low energy demand trajectories (especially 2020-2050). This seems to be a no-lose-option, with few side effects (mining for Li is an issue), compared to all other options discussed. However, this combination of solution pathways is not mentioned. Instead, potentially planet-endangering bionergy trajectories get outsized attention.	Noted. We believe our balance and treatment of bioenergy is not outsized. We have focused in Section 6.7 on several avenues for mitigaiton, including decarbonizing supply, electrification and use of alternative fuels, and efficiency and demand constraints. These are highlighted. We do, in addition, have a discussion on CDR, but we make clear that BECCS is not the only form of CDR.	Felix Creutzig	MCC Berlin & TU Berlin	Germany
17289	1	1	203	6	To me, the whole chapter looks like a competition of wind+solar versus other low-carbons sources - in particular hydro and nuclear. I was expecting a "battle" of low-carbon versus fossil sources. Authors seem to be more on the side of wind&solar and rather aginst the nuclear and hydro. The best example of this atitude is key Table 6.9 summarizing properties of different emission reduction techniques: wind and solar have very bright colors (high grades) comparing to other sources. Two problematic aspects of wind and solar: electricity storage and system integration, are described as separate topics in Table 6.9. However, it is more or less clear that hydro, nuclear, and other options do not require storage and significant modifications of the existing electricity systems. To summarize: selling "cheap and clean wind and PV" without discussing the unsolved problem of storage and (solvable) problem of system integration at the same place, is bad for the basic goal of slowing down the climate changes. Selling nuclear and hydro as worse than fossil will not help either.	Noted. The assessment is based on the literature indicated in the line of sight. We assess options separately, so storage and energy system integration are assessed as separate options and not part of a wind and solar. the feasibility of scenarios comprising multiple options is assessed in Chapter 3	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
17539	1	1	1	1	Just to say: thank you very much and congratulations on such a great draft. I enjoyed reading it and I hope my comments are useful.	Noted, and thank you!	Alaa Al Khourdajie	IPCC	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
45493	1	1	127	28	Maybe use consistently USD/MWh (used in table 6.3) or cents/kWh across chapter 6.	Taken into account. All units are being harmonized	Kornelis Blok	Delft University of Technology	Netherlands
47853	1	1	205	1	Chapter 6 misses to discuss social equity and justice considerations for energy system transitions. That is a significant shortcoming. Other chapters explicitly mention the use of UN SDG to provide a framing for wider transition impacts.	Noted. We have a full section on broader benefits of the transition in Section 6.7.7	Patrick Lamers	NREL	United States of America
51005	1	1	126	32	To summarize my global feelings about Chapter 6, 1/ Solar PV and wind power are discussed much too independently of energy storage and system integration, so much that it is not even clear that other low-carbon technologies, dispachable low-carbon technologies, do not require energy storage and do not raise by far the same system integration issues. Due to this "decoupling" of coupled problematics, many statements in sections 6.4.2.1 solar energy and to a lesser extent in section 6.4.2.2 on wind energy, are misleading because they omit to take into account this coupling. As a consequence, the benefits of low-carbon dispatchable energy sources, in particular hydropower and nuclear, are at best marginally acknowledged. 2/ This distortion culminates in Table 6.9, with the further problem that the relative rankings given for many indicators are subjective, excessively contrasted (too optimistic or too pessimistic) and questionnable. It is particularly important to produce a more balanced picture in this table as it will stay as some kind of summary of this chapter. Overselling solar PV and wind power through this decoupling does not serve in the medium to long term (nor in the sort term either) the cause of the fight against climate change. Neither is presenting nuclear as worst than fossil neither.	Noted. We have extensive discussions throughout the chapter of the need for storage and system integration to be able to integrate VRE options.	Eric PROUST	European Nuclear Society (ENS)	France
52137	1	1	127	28	The chapter sould be focused on the physical energy system itself rather than on individual components of the energy system.	Noted. We have tried to provide a systemic perspective along with a perspective on indiviual components of the system.	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
52147	1	1	127	28	Many if not most of the figures are difficult to read and interpret. Fix.	Taken into Account	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
52165	1	1	127	28	In many cases, parenthesis for reference either have an extra ")" or missing a "("; the document should be systematically checked for these typos.	Taken into Account	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
52183	1	1	127	28	Sometimes a hyphen is used instead of a dash; entire document should be checked.	Taken into Account	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
52241	1	1	127	28	Chapter uses terms related to the reliability and resiliency of the electric power system that are inconsistent and change throughout the document.	Taken into Account. We have tried to separate out these two concepts.	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
67511	1	1	100	70	Chapter 6 appears to be missing almost entirely the literature on 100% renewable energy studies. Specifically, here are the abstracts of 47 papers on the subject, only a small number of which appear in Chapter 6. http://web.stanford.edu/group/efmh/jacobson/Articles/I/CombiningRenew/100PercentPaperAbstracts.pdf I would highly suggest that this chapter be beefed up with references to these papers.	Noted. We have a full box on 100% renewable systems	Mark Jacobson	Stanford University	United States of America
79779	1	1	203		In the text there is almost no reference and evaluation of the solar heating issues, that can cover a significant part of the energy demand and can support the efforts of decarbonization. The solar heating systems can reduce the need for fossil heating energy, and can significantly support the heat pumps in delivering space heating and domestic hot water. Also, they can be used to cover the needs for many human activities, even support the efforts for solar cooling. this issue is well addressed by IRENA and REN 21, as well as from IEA please see https://www.iea.org/reports/technology-roadmap-energy-efficient-buildings-heating-and-cooling-equipment, http://www.iea-shc.org/data/sites/1/publications/Solar-Heat-Worldwide-2014.pdf, etc	Noted. We mention solar heating in Section 6.4.	Constantinos Psomopoulos	University of West Attica, Department of Electrical and Electronics Engineering	Greece
81905	1	1	127	28	Chapter 6 considerably diverts from the structure of the chapter on energy systems of AR5. It picks up new discussions which are useful, but the structure seems more random and important elements from AR5 are missing in the WG3 report. One of the important omissions in WG3 AR6 report is the discussion of lifecycle emission factors of zero emission technologies. I could not find any indications of the lifecycle emission factors assumed in the entire volume similar to the lifecycle emissions provided in Figure 7.6 of chapter 7 of AR5. There is now only the assumption that there are zero emission technologies without any discussion in the WG3 report about the range of lifecycle GHG emissions from these "zero emission" technologies, nor of the range of emissions from other energy technologies. AR5 showed that lifecycle emissions are not zero and it seems important that the IPCC provides transparent assumptions about lifecycle emissions from electricity supplied by commercially available technologies. It is important to update Figure 7.6 from AR5 in AR6 because the lifecycle emissions from certain technologies change over time and more scientific information is available now. E.g. table 7.6 only reflects 'natural gas' whereas work on 2019 IPCC refinement on national GHG inventories and other scientific findings showed considerably higher emission factors for natural gas from fracking technologies compared to conventional technologies which may be a useful addition to an updated Figure 7.6. For nuclear energy, the quoted source Warner and Heat 2012 in AR5 reports substantially lower emissions from nuclear energy than other literature reviews available. Warner and Heat 2021 conclude on a median of 12 g CO_2/kWh which is used in AR5 as the single source for nuclear emission factor despite the fact that the median seems to be an inapprorpiate metric compared to an average. Other reviews of nuclear emission factors concluded on averages of 66 g CO_2e/kWh (Sovacool 2008) or 65 g CO_2e/kWh (Lenzen 2008). Recent studies indicate that GHG emissions from decommissioning of nuclear plants have been underestimated in the past and operating lifetimes overestimated in LCA studies (Seier and Zimmermann 2014, Sovacool 2008)). After an exploitation of high uranium ore grade in the future,	Noted. As you identified, we have not conducted an assessment of lifecycle emissions. We have focused instead on the longer-term goal of getting to full net-zero energy system, which raises complications in the context of lifecycle emissions, since energy system emissions will be very low at that time. At the same time, we do note the lifecycle emissions implications of, for example, bioenergy. And, in addition, we focus on articularing a broad range of different feasbility characteristics that will influence the deployment of different technologies.	Anke Herold	Oeko-Institut e.V.	Germany

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
82327	1	1	127	28	From other chapters I see that they use ______ evidence, _________ agreement While in this Chapter, you are using ________ confidence In my head the following is more useful, please consider to change: evidence, agreement	Noted. We only need to use evidence and agreement when we cannot use a straight confidence statement.	Anna Krook-Riekkola	Luleå University of Technology	Sweden
83927	1	1	203	1	Thank you for the opportunity to serve you as a reviewer. This chapter has undergone significant change as compared to its 2020 version. The chapter has also captured important recent progresses as related wind, solar and battery. It is also very good to see that some of the erroneous statements of the past versions are already out. However, even with that positive improvements, it is surprising to see that it still repeats some of the previous flaws that I tried to point out during the last review. The views being repeated shows the presence of a significant misunderstanding about the physics of future energy system, particularly that depends on high variable renewable energy and storage. As someone who have done hourly simulations and optimizations of various kind to understand this subject for more than a decade, I understand the limitation of various research's that are being carried out in this area. At the same time, I also know the potential as well as the solutions. As a result, my short comments are simply motivated to clarify myself as a responsible scientist. While keeping my other views to later, please allow me to make the following remarks based on my scientific knowledge. First, in transitioning to high penetration of variable renewable energy (VRE) system both storage and curtailment should increase together in an optimal system as penetration increases. You can't avoid curtailment without technical and economic penalty. Thus, the best approach is to focus on arriving at optimal design that can allow optimal use of VRE. Second, 100% RE is not 100% VRE. Thus, I don't understand why this document tries to view 100% RE as 100% VRE. With my definition, I expect several integrated regions that can run on 100% RE for full energy systems without need of seasonal storage. They simply need to be a bit smarter in designing and operating their system to allow complementarity of various RE resource as long as they can provide 15% of the total electricity (including all sectors) need from non-VRE source. Thus, I did not find any plausible proof in your document in support of your views stated in this chapter as it relates to this.	Noted. We do not consider 100% RE systems to be 100% VRE systems. We address 100% renewable systems in Section 6.6.	Solomon Asfaw	LUT University	Finland
86537	1	1	1	1	Congratulations on an excellent draft chapter . Some issues that can be improvedl include: There is some repetition between sections 6.6. 6.7, 6.4. with technologies and their impacts described in more than one place.	Noted. We have tried to remove repetition, but sometimes a little is necessary for the exposition.	raphael Slade	Imperial college	United Kingdom (of Great Britain and Northern Ireland)
86539	1	1	1	1	Techology descriptions in section 6.4 need careful comparison with sector chapters, and 6.4.6 with chapter 5.	Noted.	raphael Slade	Imperial college	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
3985	1		203		The text is very clear, complete and objective. It brings, in my understanding, fundamentally all the information pertinent to the treated subject. The section is very well written and the authors were very responsible and assertive in dealing with the subject in question. For these reasons I have nothing significant to add as I understand that the topic is being treated very clearly and completely. The authors are to be congratulated for the excellent work.	Noted, and thanks!	FABIO RUBENS SOARES	USP - Universidade de São Paulo	Brazil
80081	1		203		It seems to me that there is improper usage of the term “security” instead of term “safety”.	Noted. We have checked the whole chapter and feel comfortable with the uses of "safety" and "security"	Emil Kichev	Technical University of Sofia	Bulgaria
80083	1		203		The entire text should be checked and terms “protection” and “safety”, and “security” to be used, based on their meaning:	Noted. We have checked the whole chapter and feel comfortable with the uses of "safety" and "security"	Emil Kichev	Technical University of Sofia	Bulgaria
80085	1		203		“Protection” and “Safety” denotes the protection of people and the environment against technological risks and the safety of facilities (e.g. energy systems) and activities that give rise to corresponding technological risks.	Noted. We have checked the whole chapter and feel comfortable with the uses of "safety" and "security"	Emil Kichev	Technical University of Sofia	Bulgaria
80087	1		203		“Safety” is concerned with both technological risks under normal circumstances and technological risks as a consequence of incidents, as well as with other possible direct consequences of a loss of control over an energy system or any other source of hazardous materials.	Noted. We have checked the whole chapter and feel comfortable with the uses of "safety" and "security"	Emil Kichev	Technical University of Sofia	Bulgaria
80089	1		203		“Safety measures” include actions to prevent incidents and arrangements put in place to mitigate their consequences if they were to occur.	Noted. We have checked the whole chapter and feel comfortable with the uses of "safety" and "security"	Emil Kichev	Technical University of Sofia	Bulgaria
80091	1		203		“Security” denotes the prevention and detection of, and response to, theft, sabotage, unauthorized access, illegal transfer or other malicious acts involving hazardous materials, substances or their associated facilities.	Noted. We have checked the whole chapter and feel comfortable with the uses of "safety" and "security"	Emil Kichev	Technical University of Sofia	Bulgaria
80093	1		203		“Safety measures” and “security measures” have in common the aim of protecting human life and health and the environment.	Noted. We have checked the whole chapter and feel comfortable with the uses of "safety" and "security"	Emil Kichev	Technical University of Sofia	Bulgaria
80095	1		203		The “Safety standards” concern the security of facilities and activities to the extent that they require “security for safety” measures that contribute to both “safety” and “security”, such as:	Noted. We have checked the whole chapter and feel comfortable with the uses of "safety" and "security"	Emil Kichev	Technical University of Sofia	Bulgaria
80097	1		203		(a) Appropriate provisions in the design and construction of energy systems and other facilities;	Noted. We have checked the whole chapter and feel comfortable with the uses of "safety" and "security"	Emil Kichev	Technical University of Sofia	Bulgaria
80099	1		203		(b) Controls on access to energy installations and other facilities to prevent the loss of, and the unauthorized removal, possession, transfer and use of, hazardous materials;	Noted. We have checked the whole chapter and feel comfortable with the uses of "safety" and "security"	Emil Kichev	Technical University of Sofia	Bulgaria
80101	1		203		(c) Arrangements for mitigating the consequences of accidents and failures, which also facilitate measures for dealing with breaches in security that give rise to technological risks;	Noted. We have checked the whole chapter and feel comfortable with the uses of "safety" and "security"	Emil Kichev	Technical University of Sofia	Bulgaria
80103	1		203		(d) Measures for the security of the management of hazardous sources materials.	Noted. We have checked the whole chapter and feel comfortable with the uses of "safety" and "security"	Emil Kichev	Technical University of Sofia	Bulgaria
47035	2	1	3	9	I think a section on energy efficiency (not just as part of net-zero systems) should be highlighted in this chapter of the IPCC report, as it is an integral part of any energy system and as tremendous potential for not only limiting global warming, but also providing other socioeconomic benefits that are essential for sustainable development. Having this topic mentioned instead throughout the chapter does not highlight its significance, in my view.	Noted: Energy efficiency of end uses is handled in the sectoral chapters. Here we discuss the efficiency of energy supply and, to some extent, the efffiiency of full energy systems	John Leo Algo	Living Laudato Si' Philippines	Philippines

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
85475	2	1	126	32	I know I'm not a chapter editor but this chapter is too important. I cannot let this go. I think what this chapter would benefit from most is restructuring. Currently it lacks a clear structure and is full of overlaps. On top of that, good and bad news keep alternating in a way that makes a readers head spin. If you have just a modicum of respect for your reader (who is not just your peer but can be a policy maker or working for a company) you must try to tell the story better. (My idea on how scientists should tell stories better: bit.ly/science_story) What I would do if I where you is the following: INTRODUCTION Here is where you tell the patient reader (most skip the introduction so this is for the patient ones) to settle in and prepare for the ride. You give a taste of what's to follow and prime him or her to understand what's to come using the excellent pictures that are now in 6.1. While telling the introductory story you link to the relevant paragraphs. (And the order in which you tell the story in the introduction should be the same order as that of the paragraphs in the chapter!!) I would make 6.2 part of the introduction because it breaks the narrative I'm describing to leave it in as separate paragraph and while not uninteresting seems to me a somewhat meandering description that is not tightly connected to the rest of the chapter. So see if you can use the points in 6.2 to create your introduction to the story or leave them out. RECENT DEVELOPMENTS HAVE MADE THE SITUATION WORSE Make section titles like headlines that not only tell what it is going to be about but also what the message is that you want to convey. So this would be my new name for 6.3. If you make clear from the start that this is going to be bad news people are mentally prepared for the list of problems you are going to sum up.	Rejected: Thank you for all the guidance from your deepp experience in communication. We are, unfortunately, not in a position to make such wholesale changes to the chapter.	Auke Hoekstra	Eindhoven University of Technology	Netherlands
85441	2	2	3	10	As far as I'm concerned, 6.4 (Mitigation options) and 6.6 (Key Characteristics of Net-Zero Energy Systems) are both covering a very similar topic. Normal people expect to read about solar, wind, nuclear first. Instead this is buried two levels deep in different chapters. That should really be improved. Take solar as an example. I would strongly advice you to upgrade 6.4.2.1., 6.5.1.3., to level visable o take wind and solar and upgrade them one level in the table of content and consider merging the paragraphs where they are mentioned in the table of contents. Or at least make very clear what you are going to tell about solar	Rejected: Thank you for all the guidance from your deepp experience in communication. We are, unfortunately, not in a position to make such wholesale changes to the chapter.	Auke Hoekstra	Eindhoven University of Technology	Netherlands
7733	2	11	2	11	6.3.3. is out of indentation.	Accepted	Mahmoud Abu-samha	College of Engineering and Technology, American University of the Middle East	Kuwait
17291	2	12	2	12	Table of contents is non-balanced: proposal for new title of 6.3.4, which should address all fossil fuels coal, oil and gas: "Growth of fossile fuel consumptions is remains (too) fast". Absolute growth of oil, gas and coal together is still much larger than combined absolute growth of all low-carbon energy sources. Recent trends: oil and gas experience the fastest absolute growth in primary energy in the past decade. Reference: BP, 2020	Rejected: The evidence consistently shows that a critical step for limiting warming to well below 2C is to phase out coal without CCUS. Please see section 6.7.4.	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
17293	2	13	2	14	Controversial title 6.3.5 "Solar PV and wind deployment has grown substantially but shares in global electricity generation remains low". Relative growth is fast indeed, but is unfortunately irrelevant. (Data: Absolute electricity production growth in TWh/year between 2013-2018 (source BP 2020): 1) gas growth 998, 2) wind 769, 3) coal 512, 4) solar 444, 5) hydro 357, 6) nuclear 207, 7) biomass/waste 149.) Title 6.3.5 is claiming fast growth of wind, but gas electricity is risign faster (not to mention gas growth in other industries). Claiming fast growth of solar, while coal electricity is rising faster is questionable too. Wind and solar do not deserve a special Chapter here. "Fast wind and solar growth" narrative has been around for two decades. But their absolute share is still very small. Proposal for Chapter 6.3.5 title: "Modest growth of low-carbon energy resources". Chapter should include all low-carbon sources: wind, solar, hydro, nuclear, biomass, geotherm. Comparison of absolute numbers in TWh/year should be given for each source. (Fig. 6.5 should be given also with non-cumulative graphs.)	Rejected. The growth in wind and solar is one of the most important recent events with regards to climate mitigation. We are comfortable that we have a balanced perspective by noting the relative size of wind and solar generation compared to fossil generation.	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
17295	2	15	2	16	Controversial title 6.3.6 "Limited deployment of low- to negative-carbon energy resources beyond solar PV and wind". Low-carbon electricity production growth in TWh/year between 2013-20182 (source BP 2020): wind 769, solar 444, hydro 357, nuclear 207, biomass/waste 149. Looking at these numbers I would not claim that growth in the last three categories is negligible comparing to wind+solar.	Noted. The growth rate of nuclear and other renewable sources was less than 3% per year between 2015 and 2019 whereas solar and wind growth was 18% per year during the same period. However, we have modified the title based on the text revision in this subsection	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
17297	2	17	2	17	Title 6.3.7 is missleading: "6.3.7 Battery electricity storage has advanced rapidly". Total World battery storage (17 TWh in 2018, pg. 20,line 34) is still lower than storage capacity of one single large pumped-hydro storage plant. See list of plants at wikipedia: https://en.wikipedia.org/wiki/List_of_pumped-storage_hydroelectric_power_stations. Total World battery storage 17 TWh is less than daily consuption of 2 million country Slovenia. Thus 6.3.7 is discussing a "negligible" topic. Proposal for new title: "6.3.7 Electricity storage capacities remain very low". The chapter must discuss pumped-hydro first (by far the most important storage technology). Hydrogen is probably here too.	Rejected: While battery storage amounts are still small, its improvement is widely viewed as one of the more important changes in recent years. This section is looking at trends that could have long-term meaning, not just meaning today.	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
7735	2	31	2	31	The "2" in CO2 should be subscript.	Accepted	Mahmoud Abu-samha	College of Engineering and Technology, American University of the Middle East	Kuwait
74835	2	31	2	35	There is need for consistency in writing Net-Zero.. Some have capital Z others small z	Accepted	Government of Kenya	Kenya Meteorological Service	Kenya
82533	3	5	3	5	Recommend adding a fossil fuel phase out target number to this line: "Require CO2 emissions to decrease by about 2.2% to 3.3% per year for the next 30 years…" This updated range for annual C02 reductions is helpful and it would be even more valuable if the target broke down what fossil fuel phase out would need to be to reach 2.2-3.3% Co2 reduction in the industry writ large. If possible to calculate, a fossil fuel phase out number would be an essential point to include in the summary of this chapter and also possibly in the Summary for Policymakers.	Taken into account. We have added in some specific information on coal in 2030, as that is the most important for the near term.	Constabile Kerry	Oxford University School of Geography	United States of America
731	4	1		48	Information abourt carbon credit was missing. It is important especially when the energy system are being discussed.	Rejected: This is better handled in the executive summary of policy chapters.	Alok Dhaundiyal	Szent Istvan University	Hungary

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
17299	4	1	6	26	Unbalanced "Executive summary": oil and natural gas are barely mentioned. Despite the fact that they have (unfortunately) experienced by far the fastest growth in the past decade.	Taken into account. We mention oil and gas growth	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
17301	4	1	6	26	Unbalanced "Executive summary": too much words about wind and solar PV. Non-dispatchable nature of wind and sun is not mentioned. Almost nothing is said about the semi-dispatchable hydro (growing almost as fast as wind in the last decade) and nuclear (low-carbon dispatchable source with very large potential).	Rejected. We believe we have done our best to cover the options in the short amount of space provided in an ES	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
29875	4	1	6	25	Please consider to integrate key statements in the executive summary regarding the importance of energy efficiency and cumulative energy demands from various electricity technologies	Noted. Increased energy efficiency is one of the key characteristics we mention for net-zero energy systems.	Government of Norway	Norwegian Environment Agency	Norway
61951	4	1	6	23	Executive summary: As Figure 6.1 part 2050 includes two additional things, namely "convert-other gases" and "Hydrogen" should one also discuss them in the executive summary.	Noted: The ES does mention hydrogen and other carriers, along with electrification	Esa Vakkilainen	LUT University, Lappeenranta	Finland
71513	4	1	6	25	We suggest a section in the Executive Summary which discusses the Energy Efficiency First principle (see https://enefirst.eu/).	Noted. Increased energy efficiency is one of the key characteristics we mention for net-zero energy systems.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
82291	4	1	6	26	You draw many conclusion also on sector level. I recomend you to check these with the sector chapteres within the AP6 reports, so that the report doesn't conclude different things at different parts of the report. (There can of course be different kinds of conclusions, but then it is important to explain why). E.g. check biomass with Göran Berndes or Kornelis Blok in ch12.	Taken into Account. We have tried to reconcile our results with those in the sectoral chapters.	Anna Krook-Riekkola	Luleå University of Technology	Sweden
297	4	2	4	6	The first paragraph of this chapter is not at all clear or strong. It starts by noting "produce" net zero, but then uses other verbs in the same paragraph. It also has a very fluffy time frame of around 2050-2065, and then says something about several decades later to stay under 2 degrees. Writing seems very imprecise and way too open to interpretation for likely the most important point of the whole exercise.	Accepted: the language and results have been tightened up	Morgan Bazilian	Colorado School of Mines	United States of America
17185	4	2	4	10	The first ES point describes an average growth rate of energy system emissions of 2% per year from 2000 to 2018. The following ES describes a growth rate of 1.26% per year between 2010 and 2018. To minimise confusion, I would suggest combining these two sentences in the second ES point and avoid overlapping the time frames (e.g. "Energy system emissions grew x% from 2000 to 2010 and x% from 2010 to 2019"). Also, how is the global energy system defined here? In the Ch2 analysis, energy system emissions grew 2.9% per year from 2000 to 2010, and 1.3% per year from 2010 to 2019, reaching 19.7 GtCO2eq in 2019.	Accepted. We have tried to tighten the discussion of rates, particularly since rates don't mean a lot as we get toward net zero.	William Lamb	Mercator Research Institute on Global Commons and Climate Change (MCC)	Germany
55571	4	2	4	2	Add to the Executive Summary a key finding on the RDD&D needs to achieve net zero energy systems.	Taken into Account. We now note that Advances in low-carbon energy resources and carriers such as next-generation biofuels, hydrogen produced from electrolysis, synthetic fuels, and carbon-neutral ammonia would substantially improve the economics of net-zero energy systems.	Government of United States of America	U.S. Department of State	United States of America
55573	4	2	4	2	Adding a bullet on progress toward net zero given decadal trends would be insightful.	Rejected. This can be handled in Chapter 3.	Government of United States of America	U.S. Department of State	United States of America
55575	4	2	4	6	Suggest adding statement per Section 6.7 that policy changes will be needed to achieve these goals.	Taken into Account. We have made clear that without further actions, we will not limit warming to less than 2C. We have not specificed those actions as "policy" specifically, however.	Government of United States of America	U.S. Department of State	United States of America

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55577	4	2	4	6	The discussion here should also note the importance of reducing energy-related methane and other GHGs, not just CO2. Further, the impact of methane with a 20-year GWP should be noted.	Accepted. We have included a GHG and not just a CO2 framing, although we don't call out methane in specific.	Government of United States of America	U.S. Department of State	United States of America
685	4	3			Rewrite this sentence ' The Paris goals.....'. It could be 'To comply with the Paris agreement,.....'	Taken into account -- Paris goals has been removed	Alok Dhaundiyal	Szent Istvan University	Hungary
80337	4	3	4	3	The following text is creating a confusion and either take it out or be more precise "and several decades after to limit warming to 2°C".	Accepted	Subash Dhar	UNEP DTU Partnership, DTU	Denmark
81889	4	3	4	3	"The Paris goals cannot" --> "The goals outlined in the Paris Agreement cannot", or "The Paris Agreement goals cannot"	Accepted	Pietro Guarato	Université de Lausanne	Switzerland
687	4	4			The sentence 'Reaching net-zero CO2 emissions by 2050 would…'. It needs to relook. 'Comparing to the average rise .	Taken Into Account: We have removed the long-term percentage rate reductions.	Alok Dhaundiyal	Szent Istvan University	Hungary
1691	4	4	4	5	Given current emissions level and net zero emissions by 2050, then we are sure to know the required annual rate of the derease in CO2 emissions, either about 2.2% or 3.3% in the next 30 years. How could you have both?	Taken Into Account: The ES has been revised	Taoyuan Wei	CICERO Center for International Climate Research	Norway
52269	4	4			"The Paris goals cannot be met without largely eliminating energy system CO2 emissions". the word "eliminating" is very strong and only backedup with a (medium confidence) reference	Taken into Account. The sentence has been revised.	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
55579	4	4	4	8	Providing two different growth rates for CO2 emissions from slightly different time periods seems unnecessary and slightly confusing. Are these numbers talking about the same thing?	Taken Into Account: We have removed the long-term percentage rate reductions.	Government of United States of America	U.S. Department of State	United States of America
69445	4	4	4	6	If I'm not mistaken, a reduction of fossil fuel CO2 emissions starting at 38 Gt/y by 2.2%/y over 30 years would lead to emissions of 19.5 Gt/y, while a reduction of 3.3%/y over the same period would lead to emissions of 13.9 Gt/y. Are these levels of gross emissions actually compatible with reaching net-zero CO2 emissions by 2050? Or is the necessary annual reduction 2.2% to 3.3% of current 38 Gt/y emissions, i.e 836 Mt to 1.254 Mt/y, leading in 30 years to a level of emissions between 12.9 and 0.4 Gt?	Taken Into Account: We have removed the long-term percentage rate reductions.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
30693	4	5	4	6	The last clause after "as" can be deleted because it duplicates the content of the next paragraph.	Accepted	Government of Japan	Climate Change Division - Ministry of Foreign Affairs	Japan
11443	4	6	4	6	The source of the text "average growth of over 2% per year from 2000 to 2018" cannot be identified in the main text. Please check.	Taken into account. We have checked all lines of sight	SAI MING LEE	Hong Kong Observatory	China
15083	4	7	4	7	The annual growth of energy consumption is not given in this paragraph. "In continue, energy demands and emissions have continued to rise" should be changed to "in continue, global energy emissions have continued to rise". Or this sentence remains unchanged, but then gives the growth rate of energy consumption.	Noted	Guoquan HU	National Climate Center of China Meteorological Adminstration	China
689	4	8			Replace 'grew' with surge or an appropriate word. 'the global energy system grew at..'	Rejected: Surged has a subjective tone. Grew is good.	Alok Dhaundiyal	Szent Istvan University	Hungary
63109	4	8			Need a comma between "2019 reaching"	Accepted	Jennifer Sklarew	George Mason University	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
74179	4	8	4	16	Not only is it not possible to operate a grid with 100% renewables and battery storage, the cost would be prohibitive. While later paragraphs mention the cost issues associated with nuclear, no mention is made of the overall cost that would be required for such a high percentage of renewables. The evidence of this is clearly indicated by the experience in Germany which has significantly increased costs .https://spectrum.ieee.org/energy/renewables/germanys-energiewende-20-years-later	Noted. We discuss the challenges to high penetration of VRE below	Jeffrey Merrifield	Pillsbury Law Firm	United States of America
86595	4	8	4	16	It is acknowledged within this chapter a number of times that electricity systems powered predominantly by renewables are increasingly becoming viable in various countries around the world. However, this is immediately contrasted in the chapter with a counter-argument that 100% renewable-based systems will be more difficult to obtain. Is this a useful contrast? Should you instead be discussing what is the likely point at which renewables penetration will be too high. I have not seen anywhere in this chapter an indication of where the inflection point is likely to be, between cost effective and not. If it is at 95% then that is less of a problem then the examples given in the IAM outputs of Figure 6.29. The modelling supplied with the IAMs do not get anywhere close to 100% renewable energy systems - maxing at about 65% of electricity, which is only 40% of the energy system! So why the stark contrast? Also, as the IAMs are not built to accomodate the non-linear dynamics being exhibited by solar, wind and battery technologies they don't appear fit for the purpose of answering questions around the level to which renewables can meet the world's energy demands. I believe new modelling efforts should be acknowledged that are better suited to answering such questions and avoiding making such unsubstantiated and stark contrasts (e.g. Way, Mealy, Farmer 2020).	Noted. We discuss the challenges to high penetration of VRE below	Matthew Ives	University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
61553	4	9	4	9	latest IEA 2020 energy sector global CO2 emissions estimate is 31.5Gt	Rejected We have used EDGAR database CO2 emissions from fossil fuels and industry which is more comprehensive and include significant activities not covered by IEA than IEA's.. Chapter 2	tom howes	International Energy Agency	France
699	4	11		13	Electricity generation also involves the cost of grid. The cost is reduced, but what about the power quality if it is connected to grid?	Noted. We discuss the challenges to high penetration of VRE below	Alok Dhaundiyal	Szent Istvan University	Hungary
701	4	11		13	Is it necessary to have a battery storage when the sole purpose is the commericialisation of the solar power?	Rejected: Batteries are good for cars as well. I may be misunderstanding the question	Alok Dhaundiyal	Szent Istvan University	Hungary
1743	4	11	4	17	Pumped hydro storage (PHS) should be front and centre of summaries of storage technology. Batteries are important, but PHS is more important both now and in the long run, particularly for overnight storage to support solar PV. PHS constitutes 95% of storage power and 99% of storage energy. It is much cheaper than batteries for storage of several hours or longer. Recently published work shows that there are 600,000 good sites with 23 million GWh of storage potential around the world (Matthew Stocks, Ryan Stocks, Bin Lu, Cheng Cheng, Andrew Blakers, "Global Atlas of Closed-Loop Pumped Hydro Energy Storage", Joule, 2020, https://doi.org/10.1016/j.joule.2020.11.015). This is 100X larger than needed to support 100% renewable energy. All this storage is off-river (closed loop) which avoids the need to dam rivers. A global atlas has been published: http://re100.eng.anu.edu.au/global/index.php	Rejected. This is a message about recent advances, not which technologies may or may not be most important in particular applications.	Andrew Blakers	Australian National University	Australia

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
18201	4	11	4	17	Consider removing middle sentence ('cost reductions have spurred adoption') to make clear this point is about the financial viability of energy systems. The next key point mentions uptake of systems	Accepted	Government of United Kingdom (of Great Britain and Northern Ireland)	Department for Business, Energy & Industrial Strategy	United Kingdom (of Great Britain and Northern Ireland)
37653	4	11	4	17	The text in these lines provides only part information. It should be expanded to include the fact that with increased penetration of intermittent solar and wind, system cost increases dramatically. Reliability of supply also decreases as demonstrated by rolling blackouts at several places in the recent past. As solar energy sources are inverter based, they do not provide any mechanical inertia; as a result stability issues also increase. It also needs to be mentioned that safety regulation is a major issue with battery storage. Safety regulations for battery storage are yet to be developed. In the year 2020, several fires were reported in South Korea alone (Please see Korean Times, 7 February 2021).	Noted. We discuss the challenges to high penetration of VRE below	Ravi B Grover	Homi Bhabha National Institute	India
52139	4	11	4	17	The discussion does not mention the decrease in costs in the generation of wind, both on and off shore. Should be included	Accepted	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
64587	4	11	4	14	While costs of these options have dropped as indicated, the text ignores that what matters is total system cost, including integration and spatial and temporal demand/supply pattern disparities. A caveat should be added here, as this summary suggests (what many people may think already) that a transition to renewable energy will be cheap and easy to accomplish.	Noted. We discuss the challenges to high penetration of VRE below	Government of Netherlands	Ministry of Economic Affairs and Climate Policy	Netherlands

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
76387	4	11	6	25	This content fails to acknowledge to dilemma faced by wind and solar PV that, while capital costs are lowering the Levelised Costs of Electricity (LCOE) in many jurisdictions, this is more than offset by increases system costs. Further, as policy requirements drive towards lower levels of emissions, we see an acceleration of system costs. The chapter acknowledges the benefits and potential for nuclear energy but fails to make a substantive quantified comparison of energy systems that include nuclear energy with those that exclude its use. The following comments are drawn from experiences in Australia though are applicable internationally. If we compare the costs of increasing percentages of variable renewable energy (VRE) with those of nuclear electricity key factors combine to progressively drive up the cost of VRE. 1.The intermittent output requires the provision of quick-start backup generators such as open cycle gas turbines to augment existing hydroelectric capacity or pumped storage capacity. The use of grid level electrical storage batteries are very valuable to remedy short duration grid instability caused by VRE. However, for large scale daily, weekly or seasonal energy transfers batteries are not a viable economic option even with anticipated cost reductions through to 2050. 2.As renewable generation increases the transmission and distribution costs also markedly increase. Variability and lower capacity factors of VRE cause lower utilisation of the transmission network resulting in higher transmission, distribution and ancillary services costs. Analysis shows that benefits from wind and solar PV diversity across the Australian Energy Grid (NEM) are quite marginal and come nowhere near providing a base load capability. Australia's Energy Market Operator (AEMO) said recently that marginal loss factors threatened the viability of some new renewables projects and called for urgent investment in transmission lines. Already, in Australia for example a high proportion of at least 40% low voltage electrical customer's bills are attributed to transmission and distribution even when	Noted. We discuss the challenges to high penetration of VRE below	Robert Parker	Nuclear for Climate Australia	Australia
691	4	12			Need to be refined ' Investment costs for PV dropped by 80% during the period from 2010-2020' PV system, not PV	Taken Into Account: Bullet has been revised for clarity and updated for accuracy.	Alok Dhaundiyal	Szent Istvan University	Hungary
1693	4	12	4	12	"...80% from 2010-2020" should be "...80% from 2010 to 2020"?	Taken Into Account: Bullet has been revised for clarity and updated for accuracy.	Taoyuan Wei	CICERO Center for International Climate Research	Norway
9787	4	12	4	13	Should be written as: "Investment costs for PV dropped 80% in 2010-2020 period"	Taken Into Account: Bullet has been revised for clarity and updated for accuracy.	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
11445	4	12	4	13	The source of the statement "Investment costs for PV dropped 80% from 2010-2020" cannot be identified in the main text. Please check.	Taken into account. We have checked all lines of sight	SAI MING LEE	Hong Kong Observatory	China
18199	4	12	4	13	For the text '...dropped 80% from 2010-2020. Battery costs dropped by ⅔ between 2015 and 2020...' Could the authors please consider using like-for-like change descriptors; either percentages or fractional, and same timescale 5 or 10 years for better comparison?	Taken Into Account: Bullet has been revised for clarity and updated for accuracy.	Government of United Kingdom (of Great Britain and Northern Ireland)	Department for Business, Energy & Industrial Strategy	United Kingdom (of Great Britain and Northern Ireland)
33043	4	12	4	12	the costs of fuel cells and electrolysers have also dropped rapidly. The key findings are that the dispensed price of hydrogen is likely to meet an interim target based on fuel economy-adjusted price parity with gasoline of $6.00 to $8.50 per kilogram by 2025 [https://www.greencarreports.com/news/1128428_report-hydrogen-fuel-cell-price-parity-with-gasoline-2025]	Rejected. There are many places where techonlogy has advanced, and we have chosen to focu on those that have had the biggest near-term influence. We do discuss hydrogen with electrolysis in detail in 6.4.5.	Yashar Hajimolana	University of Twente	Netherlands

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
85775	4	12	4	13	Suggest using updated figures for battery price drops and change it from a ratio (2/3) to a percentage %. BNEF reports an 87% drop in price from 2010-2019.	Taken Into Account: Bullet has been revised for clarity and updated for accuracy.	Government of Australia	Department of Industry, Science, Energy and Resources	Australia
693	4	13			Combine it with previous sentence "Battery costs dropped by ⅔ between 2015 and 2020."	Taken Into Account: Bullet has been revised for clarity and updated for accuracy.	Alok Dhaundiyal	Szent Istvan University	Hungary
9789	4	13	4	13	please edit 2/3 at: "Battery costs dropped by ⅔ between 2015 and 2020"	Taken Into Account: Bullet has been revised for clarity and updated for accuracy.	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
11447	4	13	4	13	The source of the statement "Battery costs dropped by ⅔ between 2015 and 2020" cannot be found in the main text. Please check.	Taken into account. We have checked all lines of sight	SAI MING LEE	Hong Kong Observatory	China
17303	4	13	4	13	Statement: "Battery costs dropped by ⅔ between 2015 and 2020." This info is irrelevant. Absolute price per MWh of stored energy is still typically an order of magnitude higher than pumped storage (comparison of Slovenian NGEN company Tesla battery vs. Slovenian pumped-storage plant Avče).	Noted. This message is about key technological advances.	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
28933	4	13	4	13	I propose to rephrase: "…these cost reductions and financial instruments ("support schemes") by public policy have spurred the adoption…	Noted: Sentence has been removed	Fabian Heymann	INESC TEC	Switzerland
64391	4	13	4	14	Did cost reductions spur adoption or did adoption spur cost reductions? This is a question of causality. Could it be both in a feedback loop that has led to innovation, which has resulted in the current affordability of renewable energy and battery storage systems?	Noted: Sentence has been removed	Curt Bjurlin	Stantec Consulting	United States of America
695	4	14		17	Rewrite the sentence. ' Low-carbon electricity is now cheaper than that of generated by fossil'?? Article missing	Accepted	Alok Dhaundiyal	Szent Istvan University	Hungary
697	4	14		17	What is this low-carbon electricity?	Taken into account. We have included this definition in Section 6.2	Alok Dhaundiyal	Szent Istvan University	Hungary
17305	4	14	4	17	Missleading statement: "Low-carbon electricity is now cheaper than fossil generation in many regions, electric vehicles are increasingly competitive with internal combustion engines, and large-sale battery storage on electricity grids is increasingly viable. (high confidence)". Unfortunately, shares of all these technologies are still very low.	Rejected: The sentence is still accurate. Shares take time to evolve in response to economic conditions.	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
28351	4	14	4	17	‘’Low-carbon electricity is now cheaper than fossil generation in many regions, electric vehicles are increasingly competitive with internal combustion engines, and large-sale battery storage on electricity grids is increasingly viable. (high confidence)’’ The statement definitely cannot be considered as of high confidence because: (i) Solar and wind costs of the system energy mix are estimated in the report without adding expenses for system energy storage, which becomes obligatory with the increased fraction of solar and wind power in the system, i.e. solar and wind costs are significantly underestimated in a perspective [1]. System can reliably operate without such storage only at the limited fraction of solar and wind sources; (ii) Low costs of solar and wind electricity are partially set up by its lower source quality in comparison with the traditional sources, such as fossil fuel, hydro and nuclear, because solar and wind produce highly fluctuating power, which is difficult to predict, manage and make reliable. Low reliability of fully renewable energy mix is recently confirmed by Great Texas Blackout of 2021; (iii) Economically and technologically effective solutions for high-capacity system energy storage do not exist currently. It is highly speculative to predict that they will be developed soon. Dedicated costs cannot be estimated with sufficient confidence; (iv) Electric vehicles are currently not competitive with the internal combustion engines in terms of price, milage between charging/refuelling, availability of service and power stations, etc. Battery capacity and lifetime are not sufficient. Electrical systems simply do not have necessary power to feed electrical vehicles in case of their rapid increase. The statement should be considered as of low confidence or strongly revised. 1. NEA (2019), “The Costs of Decarbonisation: System Costs with High Shares of Nuclear and Renewables”.	Noted. We discuss the challenges to high penetration of VRE below	Sevostian Bechta	KTH-Royal Institute of Technology	Sweden
51007	4	14	4	15	"Low-carbon electricity is now cheaper than fossil generation in many regions": this statement, which reffers to low-carbon electrivity produced by solar PV and wind power as mentioned at the beginning of the paragraph, is inaccurate and misleading if you do not add something like "when you do not take into account the cost to the electricity system of the means needed to compensate for their intermittence (solar) or variability (wind),". Obviously, if you need electricity at night, solar PV electricity is considerably more competitive than fossil electricity. The same holds for wind power if you need electricity during the ~75% of the time wind turbines cannot produce electricty for lack of enough wind. Right, levelized costs of solar PV and wind electricity are becoming lower that the ones of fossil-fuel generation, however the variable renewable sources do not provide the same service to the electricity system so that the comparison of levelized costs does not provide the full picture.	Noted. We discuss the challenges to high penetration of VRE below	Eric PROUST	European Nuclear Society (ENS)	France
85953	4	14	4	15	Suggest clarifying: "Low-carbon electricity is now cheaper than fossil generation in many regions." This is true but should be accompanied by caveats (noted later in the chapter) about the limitations of some forms of low-carbon electricity (mainly solar and wind) that require it to be supplemented to be made fit-for-purpose to provide 24/7/365 electricity to modern grids.	Noted. We discuss the challenges to high penetration of VRE below	Government of Australia	Department of Industry, Science, Energy and Resources	Australia
30695	4	15	4	15	Low carbon electricitiy cannot clearly be stated that it is cheaper than fossil fuel generation, for example the table 6.8, no clear shows relation between fossil fuel sectors and others. Therefore, the word "in some regions" should be added.	Rejected: "many regions" is still accurate.	Government of Japan	Climate Change Division - Ministry of Foreign Affairs	Japan
51009	4	15	4	16	"electric vehicles are increasingly competitive": too general: increasing competiveness against gas vehicles depends on the uses and on the subsidies electric vehicles benefit from	Rejected: This statement is accurate	Eric PROUST	European Nuclear Society (ENS)	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
80339	4	15	4	16	The reason electric vehicles have become competitive is also due to financial incentives and tax exemtions provided by a number of national governments	Rejected: This statement is accurate	Subash Dhar	UNEP DTU Partnership, DTU	Denmark
707	4	16			large-scale and not sale	Accepted	Alok Dhaundiyal	Szent Istvan University	Hungary
7737	4	16	4	16	Change "large-sale battery" to "large-scale battery"	Noted. These look the same	Mahmoud Abu-samha	College of Engineering and Technology, American University of the Middle East	Kuwait
51011	4	16	4	17	"large-sale battery storage on electricity grids is increasingly viable": "increasingly viable" is a particularly fuzzy concept which opens to all sorts of interpretations and therefore is misleading. Especially when what is meant by viable is not defined and when the temporal horizon considered is not indicated and when "large-scale" is not defined. Such a formulation should be proscribed from such a report. This statement should be clarified/reformulated.	Rejected. We believe this word effectively describes the situation. Electric batters are increasingly being deployed in electric grids.	Eric PROUST	European Nuclear Society (ENS)	France
61743	4	16	4	17	The statement that "large-scale battery storage on electricity grids is increasingly viable" is at best misleading. No long-term battery storage, e.g., to buffer wind power, is viable yet, as grid-scale batteries are mainly used for frequency control, as backup and to replace expensive peaker plants. The largest grid-battery at the time of writing, Hornsdale, will have max output of 150 MW and energy content of <200 MWh (with the expansion now under construction). Nor is battery storage viable to buffer the substantial seasonal variation of solar energy in higher latitudes in northern Europe and North America.	Rejected. We believe this word effectively describes the situation. Electric batters are increasingly being deployed in electric grids.	Rauli Partanen	Think Atom	Finland
65775	4	16	4	17	The statement that "large-scale battery storage on electricity grids is increasingly viable" is at best misleading. No long-term battery storage, e.g., to buffer wind power, is viable yet. Nor is battery storage viable to buffer the seasonal variation of solar energy in higher latitudes in northern Europe and north America.	Rejected. We believe this word effectively describes the situation. Electric batters are increasingly being deployed in electric grids.	Eero Hirvijoki	Aalto University	Finland
77189	4	16	4	17	While it is clear that a progress from n/100 to (n+1)/100 marks indeed an increase of readiness, it is less obvious the implication of such progress in a perspective of viability: it makes a difference where actually n falls in the scale 0-99... The use of "viabe" here seems to indicate a higher maturity than the actual one, and should probably be worth of rephrasing.	Rejected. We believe this word effectively describes the situation. Electric batters are increasingly being deployed in electric grids.	Giacomo Grasso	ENEA	Italy
77321	4	16	4	16	Replace "large-sale battery storage" with "large-scale battery storage"	Accepted	Atle Harby	SINTEF Energy Research	Norway
20865	4	17	4	17	Please precise the definition of viable.	Rejected. We believe this word effectively describes the situation. Electric batters are increasingly being deployed in electric grids.	Government of France	Ministère de la Transition écologique et solidaire	France
37073	4	17	4	24	No discussion about nuclear industry	Accepted	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
51013	4	17	4	17	"(high confidence)". This indication is only valid for the first 3 sentences of the paragraph, not for the last sentence beginning at line 14 ("Low-carbon …increasingly viable") as it is currenlty written (Cf. my 3 previous comments).	Rejected. We believe this word effectively describes the situation. Electric batters are increasingly being deployed in electric grids.	Eric PROUST	European Nuclear Society (ENS)	France
703	4	18			are they different bodies or one? If different use 'have' 'Installed wind and solar PV capacity has increased substantially in recent years'	Accepted	Alok Dhaundiyal	Szent Istvan University	Hungary

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
2623	4	18	4	26	In my opinion this paragraph reads a bit odd because the 9% solar and wind (1st sentence) and the 40% low carbon electricity (pen-ultimate sentence) seem to conflict. I'd suggest to briefly mention where the other 31% come from.	Accepted.	Jan Wohland	ETH Zurich	Switzerland
11449	4	18	4	19	The source of the text "Installed wind and solar PV capacity has increased substantially in recent years. Combined they constituted 9% of global electricity generation in 2020" cannot be found in the main text. Please check.	Taken into account. We have checked all lines of sight	SAI MING LEE	Hong Kong Observatory	China
15819	4	18	4	26	"Installed wind and solar PV capacity (…) are poised for large-scale deployment over the coming decade (…). Growth of other low-carbon electricity sources has been limited. (…) Low-carbon electricity will need to produce almost 100% of global electricity by 2050 to limit warming to for either 1.5°C or 2°C." For all the reasons developed in my other remarks in Chapter 6, it should be added here that the whole portfolio of decarbonised or very low carbon technologies in regions where they are affordable, available and mature today should be used. Strategies that rely too early and too exclusively on the development of too few technologies (solar PV, wind power and biomass) will be more costly. Strategies that globally avoid or hardly use hydro-electricity, nuclear power and fossil-fuel with Carbon Capture and Sequestration (CCS) are poised to be "non-optimal" i.e. more expensive for scenarios C1, C2 and C3 and as a result more difficult to be accepted by society.	Rejected: This is an interesting point, but it doesn't fit in the ES	Jean-Michel Trochet	EDF group (French Utility)	France
17307	4	18	4	26	"… wind and solar PV … are poised for large-scale deployment over the coming decade". I hope I am wrong, but the wind and solar PV growth rates in the past decade do not give me a hope that they might grow faster than fossil fuels. Especially in the absence of the large-scale electricity storage, where capacities are 4 to 5 orders of magnitude too low for large scale deployment. To reduce CO2 emissions, World will need much more than just wind and solar PV.	Noted	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
18203	4	18	4	26	Heading states 9% global electricity produced by Wind and PV (line 18), within paragraph it states low carbon electricity makes up less than 40% of global electric production. What is filling in that gap from 9% up to (let's say) 39%? That's 30% of low-carbon emission not accounted for. It goes on to state that Solar and PV have had the biggest increase in percentage share. I don't think this is clearly worded to discuss growth of low-carbon electricity - it implies that Wind and PV are the biggest percentage share of low-carbon electricity generation, not the biggest growth.	Taken into Account. We have provided more information for a more balanced assessment	Government of United Kingdom (of Great Britain and Northern Ireland)	Department for Business, Energy & Industrial Strategy	United Kingdom (of Great Britain and Northern Ireland)
28353	4	18	4	20	''Installed wind and solar PV capacity has increased substantially in recent years. Combined they constituted 9% of global electricity generation in 2020 and are poised for large-scale deployment over the coming decade''. The second sentence is misleading. The installed capacities of wind and solar power cannot be used for understanding of their actual contributions into the generated energy mix because their capacity factor is much lower in comparison with the other sources. As concluded in [1], "Nuclear has the highest capacity factor of any other energy source—producing reliable, carbon-free power more than 92% of the time in 2016. That's nearly twice as reliable as a coal (48%) or natural gas (57%) plant and almost 3 times more often than wind (35%) and solar (25%) plants." The statement should be revised. 1. https://www.energy.gov/ne/articles/what-generation-capacity	Taken into Account. We have provided more information for a more balanced assessment	Sevostian Bechta	KTH-Royal Institute of Technology	Sweden
55581	4	18	4	26	Add language on knowledge needed to operate high RE grids and research needed for VERY high VRE systems.	Noted. We discuss the challenges to high penetration of VRE below	Government of United States of America	U.S. Department of State	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
64393	4	18	4	26	It would be helpful to define wind and solar as "low-carbon" electricity sources at the outset of the paragraph. I think of them as zero carbon electricity sources but see that you may be including carbon cost to manufacture and install. It would also be helpful to provide absolute value of increase in wind and solar from 2013-2018 in addition to %, because solar started at a lower number of installed MW, so 215% increase could potentially be a lower amount of installed MW than 75% increase for wind.	Taken into account: we are now using "low- and zero-carbon" sources.	Curt Bjurlin	Stantec Consulting	United States of America
709	4	19			Avoid bombastic words. Use 'ready' and not poised	Taken into account. We have removed the phrase "and are poised for continued expansion"	Alok Dhaundiyal	Szent Istvan University	Hungary
30697	4	19	4	19	Wind and PV capacity posised for large scale deployoment possibly in some regions but not all. Therefore, "in some regions" should be added to the line.	Taken into account. We have removed the phrase "and are poised for continued expansion"	Government of Japan	Climate Change Division - Ministry of Foreign Affairs	Japan
705	4	21			low-interest ' hypen'	Reject: Not grammatically correct	Alok Dhaundiyal	Szent Istvan University	Hungary
11451	4	21	4	22	The source of the statement "From 2013 to 2018, low-carbon electricity generation increased by 23%" cannot be identified from the main text. Please check.	Taken into account. We have checked all lines of sight	SAI MING LEE	Hong Kong Observatory	China
61745	4	21	4	23	"From 2013 to 2018, low-carbon electricity generation increased by 23%. The vast majority of the growth was solar PV and wind power, which grew by 215% and 75%." Please give these three increases (low-carbon total, solar, and wind) in TWh/year as well, since percentage growth is highly dependent on what the baseline is that growth happens from. Add for example: "During 2013-2019 the global annual production grew in hydro 408 TWh, solar 584 TWh, and wind 795 TWh (https://ourworldindata.org/renewable-energy). In China, nuclear grew by 250 TWh during this period but the majority of this growth was countered by the premature, policy-induced shutdowns elsewhere. Still, nuclear grew by 230 TWh (12%) from 2013 to 2019 (BP Energy Statistics 2020)".	Accepted	Rauli Partanen	Think Atom	Finland
65777	4	21	4	23	"From 2013 to 2018, low-carbon electricity generation increased by 23%. The vast majority of the growth was solar PV and wind power, which grew by 215% and 75%." Please give these three increases (low-carbon total, solar, and wind) in TWh as well instead of only in percentages and compare them, e.g., with the increase in hydro in TWh. During 2013-2019 the global annual production grew in hydro 408 TWh, solar 584 TWh, and wind 795 TWh (https://ourworldindata.org/renewable-energy). In China, nuclear grew by 250 TWh during this period but the growth was countered by the premature, policy-induced shutdowns elsewhere. This gives a better view of the status of the field.	Accepted	Eero Hirvijoki	Aalto University	Finland
11453	4	22	4	23	The source of the text "The vast majority of the growth was solar PV and wind power, which grew by 215% and 75%" cannot be found in the main text. Please check.	Taken into account. We have checked all lines of sight	SAI MING LEE	Hong Kong Observatory	China
77323	4	22	4	24	The way of describing growth in low-carbon electricity generation is biased when only using percentage growth. For instance, solar PV has a large growth in percentage (215%) from 139TWh to 554TWh according to IEA, adding 415TWh of new generation. However, hydropower has a smaller percentage growth, but has added more generation (435TWh) than solar PV. I suggest also to give absolute numbers, not only percenage growth	Accepted	Atle Harby	SINTEF Energy Research	Norway
711	4	23		24	What are these low-carbon electricity sources? Information missing	Rejected. Readers can check out the chapter to learn more about low-carbon sources. There is not sufficient space for definitions in the ES.	Alok Dhaundiyal	Szent Istvan University	Hungary
713	4	23			Avoid 'grew' use proper words. 'respectively' after 75%	Taken into account: Sentence has been rewrittent	Alok Dhaundiyal	Szent Istvan University	Hungary

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
715	4	23			growth or scope?	Rejected. Growth is the correct word.	Alok Dhaundiyal	Szent Istvan University	Hungary
74837	4	23	4	26	There is need to add the word respectively after the sentence "which grew by 215% and 75%" in line 23. In Line 26, delete the word for in the sentence 'limit warming to for either 1.5°C or 2°C.".	Taken into account: Sentence has been rewrittent	Government of Kenya	Kenya Meteorological Service	Kenya
77191	4	23	4	26	Moving from wind and solar (9% altogether) to the whole set of low-carbon electricity generation technologies, where hydro (16%) and nuclear (10%) play the most part of the total (40%) is misleading. These last three sentences should be moved in a separate block, after hydro and nuclear have been discussed. See following comment for a proposal.	Taken into Account: We have presented more information on other sources	Giacomo Grasso	ENEA	Italy
4167	4	24	4	24	A few select reasons why "other low carbon electricity sources has been limited" would be helpful - political, geograaphical…	Rejected: Space constraints	Neil M. Mulchan	Adventure Physics, LLC	United States of America
28355	4	24	4	25	The statement that “Low-carbon electricity generation technologies currently produce less than 40% of global electricity. (high confidence)” should be complemented by examples of specific national grid systems, and/or by precising that some countries have already succeeded in decarbonisation of electricity production for more than 90%, owing to a combination of hydropower and nuclear energy. Example of Sweden is very instrumental. Thanks to Hydro (39%) and Nuclear (41%), low-carbon electricity generation in Sweden [1] is close to 100% even at the background of limited Wind (10%) and small Solar (0.2%). Replacement of nuclear by wind and solar in Sweden will not reduce carbon emissions but can be technologically/economically difficult and can reduce reliability of electrical system. 1. https://www.energimyndigheten.a-w2m.se , p.6	Rejected: Space constraints	Sevostian Bechta	KTH-Royal Institute of Technology	Sweden
20867	4	25	4	26	This conclusion is very important and should be the title of this paragraph. This is a necessary condition to achieve net-zero CO2 of the energy system. Besides, it seems from elements in 6.7.1.2 that the "medium confidence" only applies to 2°C, not 1,5°C (which could be mentionned as "high confidence").	Taken into Account. This point has been moved to a separate bullet on benchmarks for the low-carbon transition	Government of France	Ministère de la Transition écologique et solidaire	France
51015	4	25	4	26	“Low-carbon electricity generation technologies currently produce less than 40% of global electricity”: consider changing to “Low-carbon electricity generation currently amounts to less than 40% of global electricity production and is still dominated by hydropower and nuclear energy sources”. This would better complete the global picture given in this paragraph.	Taken into Account: We have presented more information on other sources	Eric PROUST	European Nuclear Society (ENS)	France
51017	4	25	4	26	"Low-carbon electricity will need to produce almost 100% of global electricity by 2050 to limit warming to for either 1.5°C or 2°C". This sentence is a very important conclusion and therefore should in bold	Taken into Account. This point has been moved to a separate bullet on benchmarks for the low-carbon transition	Eric PROUST	European Nuclear Society (ENS)	France
717	4	26			what is going to be 'warm'? Global warming? Warming of earth or what?	Rejected: Implied	Alok Dhaundiyal	Szent Istvan University	Hungary
42959	4	26	4	26	remove the "for" at the end of this sentence	Accepted	Kurt Kornelsen	Ontario Power Generation	Canada
51019	4	26	4	26	"medium confidence" only applies to 2°C; 1.5°C could be mentioned as "high confidence".	Taken into account. The sentence has been revised	Eric PROUST	European Nuclear Society (ENS)	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
77193	4	26	4	27	PROPOSAL. Addition of the following new block here: "Hydroelectric and nuclear constituted 16% and 10% of global electricity generation in 2020, respectively. The growth of such low-carbon electricity sources however has been limited. Altogether, low-carbon electricity generation technologies currently produce less than 40% of global electricity. (high confidence) Low-carbon electricity will need to produce almost 100% of global electricity by 2050 to limit warming to either 1.5°C or 2°C. (medium confidence) {6.3, 6.4}" Then, block in page 5, lines 17-28 is proposed to be moved hereafter.	Taken into Account: We have presented more information on other sources like hydroelectric power.	Giacomo Grasso	ENEA	Italy
17201	4	27	4	27	It would be very useful to have some supporting figures and analysis for this ES point, wherein recent regional emissions trends are described (e.g. to show where energy system emissions are accelerating, or are stable; perhaps decomposing these trends by fossil share and intensity), as well as upcoming investments (e.g. the pipeline of new coal power plants). For the former, there is much literature from the Global Carbon Project that could fill out an additional paragraph/figure in section 6.3.1.	Taken into account. Regional emissions are discussed in 6.3, including a decomposition, and in 6.7, and the sentnece in the ES has been revised.	William Lamb	Mercator Research Institute on Global Commons and Climate Change (MCC)	Germany
20869	4	27	4	28	Not really consistent with the two preceeding paragraphs which were refereing to the increased investment in renewable sources of energy and not an investment trend in fossil sources of energy. Some explainations are required before.	Taken into account. This paragraph has been rewritten for clarity.	Government of France	Ministère de la Transition écologique et solidaire	France
51021	4	27	4	27	as written at this place, appears somewhat contradictory with the previous paragraph. Need for a better articulation	Taken into account. This paragraph has been rewritten for clarity.	Eric PROUST	European Nuclear Society (ENS)	France
82079	4	27	4	35	The tone in the tekst seems fairly negative. Although the argumentation is correct it could be complemented with information mentioning also the positive aspects. For example, this paragraph could mention that although the continued investments in inefficient technologies and infrastructure can slow down the achievement of the Paris Agreement goals, investments in renewable technologies has increases by x% in the past years, or mention how have investments in emitting and inefficient technologies infrastructures have changed in the past years.	Taken into account. This paragraph has been rewritten for clarity.	Sofia Rosero Abad	University	Netherlands
4169	4	30	4	31	Include statement on: "Societal dogma on anthropogenic climate change" as an additional reason for impeding change.	Rejected. Not addressed in the chapter.	Neil M. Mulchan	Adventure Physics, LLC	United States of America
28935	4	30	4	31	I propose to rephrase: "Physical infrastructure like electric power plants, pipelines, or buildings are planned and commissionned over extended time periods (several years) and can last for decades	Rejected: To detailed for ES. Paragraph has been simplified and refocused.	Fabian Heymann	INESC TEC	Switzerland
15821	4	31	4	35	"Continued investments in emitting or inefficient infrastructure, particularly investments in coal-fired electricity, will substantially increase the challenge of meeting the Paris goals." In terms of message, "in coal-fired electricity" should be completed by "coal-fired and gas-fired electricity and premature retirement of existing low-carbon technologies (hydro and nuclear).	Rejected: To detailed for ES. Paragraph has been simplified and refocused.	Jean-Michel Trochet	EDF group (French Utility)	France
719	4	36			It is not necessary unless it is mentioned by the authors. 'future source' 'weather dependence'	Noted: We do not understand this comment	Alok Dhaundiyal	Szent Istvan University	Hungary
43261	4	36	4	46	In these projections, electricity generation through non-conventional renewable energies for country is not contemplated?	Taken into account. In shortening the message, we have noted "many low-carbon" systems to be clear that not all systems.	Government of Chile	Ministry of Environment	Chile

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
43747	4	36	4	44	While it is highly relevant to assess impacts of climate change on power supply on the hand, the chapter lacks a sufficient assessment of side-effects/co-benefits of de-centralized energy infrastructure on supply security and resilience/ vulnerability to weather events on the other hand. This is highly relevant for small islands in terms of current investment decisions in energy supply infrastructure. Additional information would be appreciated.	Taken into account. We now have a box on energy system reliience in 6.5. Unfortunately, we do not have sufficient space to go beyond that box.	Government of Jamaica	Meteorological Service Division	Jamaica
47447	4	36	4	44	Unfortunately, a sufficiently detailed risk/benefit assessment of decentralised energy infrastructure is missing, in particular in the context of supply security and resilience to extreme weather events. For SIDS, this represents much needed information that is required for the planning of and investment in new energy supply infrastructure. Please expand!	Taken into account. We now have a box on energy system reliience in 6.5. Unfortunately, we do not have sufficient space to go beyond that box.	Government of Saint Lucia	Department of Sustainable Development - Ministry of Education, Innovation, Gender Relations and Sustainable Developement	Saint Lucia
64395	4	36	4	44	I think it would be beneficial to rephrase this paragraph to highlight the inherent tradeoff between climate mitigation and climate adaptation in energy systems. Any given entity, whether they be governmental, utility, or other, will have a finite budget for modifications to the energy system. As the needs for climate adaptation increase, budgets will naturally be allocated to immediate adaptation needs, potentially reducing the funds to aggressively engage in mitigation and the ET. We are already seeing the strain that climate change has placed on energy systems in places like California (wildfires), Texas (extreme cold), and coastal communities (storm damage). For me, this paragraph reads like a changing climate will affect low-carbon generation, but a changing climate is also affecting current infrastructure, and this may reduce budgets to aggressively engage in the ET as climate disruptions increase in frequency and severity.	Noted. We have shortened the paragraph to be less definitive and detailed.	Curt Bjurlin	Stantec Consulting	United States of America
725	4	37			Need comma 'change impacts locally nationally and potentially influencing' or rewrite 'Future low-carbon power sy..'	Noted. The message has been substantially shortened.	Alok Dhaundiyal	Szent Istvan University	Hungary
721	4	38			Incorrect use of perposition. ' implications for'	Noted. The message has been substantially shortened.	Alok Dhaundiyal	Szent Istvan University	Hungary
20871	4	38	4	42	Climate change could also lead to increased low-carbon energy production through altered wind patterns for instance.	Noted. The message has been substantially shortened.	Government of France	Ministère de la Transition écologique et solidaire	France
77325	4	38	4	41	suggest to add "altering wind power potential by stronger variation in wind, and changing solar power output by changing cloud cover" to sentence betweenn "altering hydropower potential" and "bioenergy and agricultural yields"	Noted. The message has been substantially shortened.	Atle Harby	SINTEF Energy Research	Norway
80581	4	38	4	38	Climate change may have both positive and negative implications on energy supply and demand.	Noted. The message has been substantially shortened.	Olga Savchuk	Instituto Superior Tecnico	Portugal
727	4	39			Climate change will likely have	Noted. The message has been substantially shortened.	Alok Dhaundiyal	Szent Istvan University	Hungary
9143	4	39	4	41	Also wind and solar will be impacted by new climate patterns (including the possibility to decrease of the efficiency of the present wid farms, due to the changing in the wind patterns).	Rejected. As we discuss in 6.5, wind and solar will be affected, but the evidence does not suggest that these sources will be affected to such an extent that it would compromise their ability to reduce emissions.	Marin Constantin	RATEN ICN	Romania

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
51023	4	39	4	41	climage change will also alter wind power (altered wind patterns) and solar PV (impact of temperature on efficiency)	Rejected. As we discuss in 6.5, wind and solar will be affected, but the evidence does not suggest that these sources will be affected to such an extent that it would compromise their ability to reduce emissions.	Eric PROUST	European Nuclear Society (ENS)	France
723	4	42			heatwaves 'remove space'	Noted. The message has been substantially shortened.	Alok Dhaundiyal	Szent Istvan University	Hungary
82081	4	42	4	44	This should point to the importance of new systems like smart grids that can better deal with these changes.	Noted. Thes sentence has been removed	Sofia Rosero Abad	University	Netherlands
729	4	45			Climatic factors effect these 'carbon-neutral energy system' . What are those ?	Noted. There is insufficient space in the ES to produce all necessary definitions. Please see the chapter for more details.	Alok Dhaundiyal	Szent Istvan University	Hungary
18205	4	45	5	6	There is repetition within the list: 'remove CO2 from the atmosphere', 'and use of some level of carbon dioxide removal'. Make clearer if these are referring to different approaches.	Taken into account. We have tried to be clearer that the first characteristic applies to overall electricity CO2, and the last is about the use of CDR, which can be in electricity or elsewhere.	Government of United Kingdom (of Great Britain and Northern Ireland)	Department for Business, Energy & Industrial Strategy	United Kingdom (of Great Britain and Northern Ireland)
28395	4	45	5	7	The key common characteristic of carbon-neutral energy systems is large scale deployment of wind and solar. State clearly that this is the basis of all of these systems, after which electrification, alternative fuels, sector coupling etc. are all relevant as well	Rejected: There isn't sufficient space to explore the multiple different possible configurations that countries or localities may utilize to bring down electricity sector emissions. Some countries may rely heavily on hydropower, for example, particularly if they are able to constrain electricity demand.	Naud Loomans	Eindhoven University of Technology	Netherlands
82083	4	45	5	7	Carbon neutral energy systems as mentioned in this paragraph require that the share of renewables in the energy mix is high. This, in turn, requires widespread deployment of wind and solar energy. It should be clearly stated that this is the basis of all the carbon neutral energy systems.	Rejected: There isn't sufficient space to explore the multiple different possible configurations that countries or localities may utilize to bring down electricity sector emissions. Some countries may rely heavily on hydropower, for example, particularly if they are able to constrain electricity demand.	Sofia Rosero Abad	University	Netherlands
85469	4	45	5	7	You seem to forget another important shared characteristic here. All these systems will contain large amounts of wind and solar (at least over 50% but probably over 75%.) At least that's what I understood after reading chapter 6, so I think that for clarity it's important to mention it here too.	Rejected: There isn't sufficient space to explore the multiple different possible configurations that countries or localities may utilize to bring down electricity sector emissions. Some countries may rely heavily on hydropower, for example, particularly if they are able to constrain electricity demand.	Auke Hoekstra	Eindhoven University of Technology	Netherlands
37655	4	46	5	1	This part of the text should be modified to say electricity systems that produce zero CO2 based on a broad portfolio of energy sources scuh as hydro, nuclear, solar and wind, or remove CO2 from the atmosphere;…..	Rejected: Insufficient space.	Ravi B Grover	Homi Bhabha National Institute	India
1665	4		6		The executive summary is absolutely outstanding and really summarizes many results and clear statements on 3 pages. It is a measure of how it should look exactly. Absolutely great!	Noted: Thanks!	David Novak	DIPLOMA Fachhochschule Nordhessen, https://www.diploma.de/, owner of the chair of sustainability	Germany
733	5	1		7	Can we not use the chemical looping combustion technique?The redox reaction can miminse the CO2 and it can be used in all types of Carbon rich fuels. Quite flexible and easy to install. Or water gas+ methanisation after gasification of coal	Noted: We don't understand the comment.	Alok Dhaundiyal	Szent Istvan University	Hungary

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
69447	5	2	5	2	I would tend to replace "light-duty" with ground or terrestrial. More and more it appears that battery electric vehicles, in case with the support of electric roads, can decarbonise the bulk of heavy duty transport.	Rejected. We agree that electrification may well go beyond this specific list. But we are also here just highlighting examples where the literature is pretty clear. So we agree with the reviewer on the point, but just don't see it as fitting within the way the paragraph is written.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
69449	5	2	5	2	I would suggest adding "industrial heat" to the list of end uses prone to widespread electrification. Among possible references on this I would mention the IEA World Energy Outlook 2020 Chapter 4 (Figure 4.10); and Maddedu et alii, 2020, The CO2 reduction potential for the European industry via direct electrification of heat supply, Environ. Res. Lett. 15 124004; Lord, M., 2018, Electrifying industry, Beyond Zero Emission, bze.org.au; and Hasanbeigi A. et alii, 2021, Electrifying U.S. Industry, www.globalefficiencyintel.com/	Rejected. We agree that electrification may well go beyond this specific list. But we are also here just highlighting examples where the literature is pretty clear. So we agree with the reviewer on the point, but just don't see it as fitting within the way the paragraph is written.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
71515	5	2	5	2	"substantially lower use of fossil fuels" is not clear enough about the need to combine any fossil fuel use with CDRs.	Rejected. In the space we have in the ES, we are limited on how many points we can make. This point is made throughout the chapter.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
17309	5	3	5	3	hydrogen and ammonia are mentioned as fuels. I prefer to use the term "energy carriers"	Accepted	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
48001	5	3	5	3	This excerpt restricts biofuels use to a 'targeted use', to substitute for fossil fuels in harder to decarbonize sector. While this may be true by 2050 (2050 (provided that electromobility combined with zero- or negative electricity systems is widespread), in the near- and mid-term biofuels are expected to remain key in many countries and regions at least in the near- to mid-term, in parallel to the progressive introduction of all infrastructure changes associated with the described energy system transformations. Therefore, this passage should at least clarify the timescale being considered and qualify the statement, since for many countries alternative fuels are expected to play a more prominent role especially in the near- to mid-term. Exclusive focus on the expected outcomes of high electrification, net-zero scenarios by 2050 may induce readers to reach wrong conclusions about potential uses of different mitigation options at least until electromobility become more widely available. By ignoring such nuances, this passage becomes somewhat incoherent with the overall message - correctly highlighted throughout the SOD - that near-term climate action is fundamental. It should be noted that different excerpts of Chapter 6 already hint on the need to evaluate the role of alternative fuels – especially, of biofuels – in more nuance in such scenarios: "Many studies focus on electrification as an end use decarbonisation strategy and do not consider significant contributions from biofuels or other renewable fuels (Bauer et al. 2018a). These studies typically assume a constrained set of available technologies to demonstrate the technical feasibility of very high renewable systems and are not optimising to find least-cost, technology neutral decarbonisation pathways (Jenkins et al. 2018b)." (p. 86, l. 8-12). In other regions, however, that may not necessarily be the case, and a comparatively lower use of electricity may coexist of higher levels of biofuels penetration, as it is correctly summarized in the following passage:	Taken into account. We have removed "targeted".	Marcelo moreira	UNICAMP - Agroicone	Brazil

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
50921	5	3	5	3	This excerpt restricts biofuels use to a 'targeted use', to substitute for fossil fuels in harder to decarbonize sector. While this may be true by 2050 (2050 (provided that electromobility combined with zero- or negative electricity systems is widespread), in the near- and mid-term biofuels are expected to remain key in many countries and regions at least in the near- to mid-term, in parallel to the progressive introduction of all infrastructure changes associated with the described energy system transformations. Therefore, this passage should at least clarify the timescale being considered and qualify the statement, since for many countries alternative fuels are expected to play a more prominent role especially in the near- to mid-term. Exclusive focus on the expected outcomes of high electrification, net-zero scenarios by 2050 may induce readers to reach wrong conclusions about potential uses of different mitigation options at least until electromobility become more widely available. By ignoring such nuances, this passage becomes somewhat incoherent with the overall message - correctly highlighted throughout the SOD - that near-term climate action is fundamental. It should be noted that different excerpts of Chapter 6 already hint on the need to evaluate the role of alternative fuels – especially, of biofuels – in more nuance in such scenarios: "Many studies focus on electrification as an end use decarbonisation strategy and do not consider significant contributions from biofuels or other renewable fuels (Bauer et al. 2018a). These studies typically assume a constrained set of available technologies to demonstrate the technical feasibility of very high renewable systems and are not optimising to find least-cost, technology neutral decarbonisation pathways (Jenkins et al. 2018b)." (p. 86, l. 8-12). In other regions, however, that may not necessarily be the case, and a comparatively lower use of electricity may coexist of higher levels of biofuels penetration, as it is correctly summarized in the following passage:	Taken into account. We have removed "targeted".	Government of Brazil	Ministry of Foreign Affairs of Brazil	Brazil
60447	5	3	5	3	CO2-based fuels/e-fuels should be added in the list of alternative fuels	Rejected. We are space limited, and the list is not exhaustive.	Célia Sapart	Université Libre de Bruxelles / CO2 Value Europe	Belgium
76307	5	3	5	3	CO2-based fuels/e-fuels should be added in the list of alternative fuels	Rejected. We are space limited, and the list is not exhaustive.	Deepak PANT	Flemish Institute for Technological Research (VITO)	Belgium
78803	5	3	5	3	In the list of alternative fuels, please add the example of "CO2-based fuels" or "synthetic fuels" This includes for instance efuels or solar fuels or recycled carbon fuels	Rejected. We are space limited, and the list is not exhaustive.	Sylvain Nizou	CEA	France
83691	5	3	5	3	CO2-based fuels/e-fuels should be added in the list of alternative fuels	Rejected. We are space limited, and the list is not exhaustive.	Christian Breyer	LUT University	Finland
85955	5	4	5	4	Suggest clarifying: "harder to decarbonise sectors". What sector are the authors comparing to? The electricity sector?	Taken into account: We have clarified that we are talking about sectors that are not as amenable to electrification.	Government of Australia	Department of Industry, Science, Energy and Resources	Australia
18211	5	5	5	6	Inconsistent terminology useage. CO2 = Carbon Dioxide. Switching between the two overcomplicates the point. Is 'carbon-dioxide capture' the correct terminology here or should it be carbon capture? Consider revising to one consistent term used - CO2 (not carbon dioxide) and Carbon Capture	Accepted	Government of United Kingdom (of Great Britain and Northern Ireland)	Department for Business, Energy & Industrial Strategy	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
55583	5	6	5	6	Is the reference included in this sentence meant to be for BECCS (bioenergy with carbon capture and storage), rather than bioenergy with CCUS?	Taken into Account. Sentence has been revised	Government of United States of America	U.S. Department of State	United States of America
60449	5	6	5	6	Here CCUS means CCS (Bioenergy with CCS => BECCS), so it should be modified and CCU should be cited distinctly. CSS and Carbon Capture and Use (CCU) distinctly differ regarding their CO2 reduction potential, the underlying technical processes and outcomes, their effects on climate mitigation, their business models and their environmental policy targets. Therefore, presenting commingling CCS and CCU does not do justice to the specific characteristics of the two concepts and could be counterproductive for the further development particularly of CCU. Therefore the term CCUS should be separated in CCS and CCU and both options should be clearly addressed independently (Cuéllar-Franca and Azapagic, 2015, Bruhn et al., 2016, Arning et al., 2019). Please note that the definition formerly given of CCUS in the glossary (If the CO2 is stored in a product for a climate-relevant time horizon, this is referred to as CO2 capture, utilisation and storage (CCUS)) is not correct and is incoherent with the use of the term CCUS in the report as in most cases CCUS is used in the context of Carbon Capture and (geological) Storage. The high level report of the Science Advice for Policy by European Academies (SAPEA) has explicitily said: " measures, regulations and incentives should examine CCU in a holistic, integrated, coordinated and transparent manner » (SAPEA, 2018).•SAPEA, 2018, Science Advice for Policy by EU Academies, Novel Carbon Capture and Utilisation Technologies-Research and Climate Aspects, Evidence Review Report, 2.•Arning et al. 2019, Energy Policy, 125, 235–249.•Bruhn et al., 2016, Environmental Science & Policy, 60, 38–43.•Cuéllar-Franca and Azapagic, 2015, J.CO2.Utili., 9, 82-102.	Accepted. We have addressed this throughout the text.	Célia Sapart	Université Libre de Bruxelles / CO2 Value Europe	Belgium
69451	5	6	5	6	I would remove "utilisation" in here, as carbon dioxide capture and utilisation, while it might be useful to mitigate emissions, cannot exemplify the concept of "carbon-dioxide removal" as suggested in this sentence. Furthermore, the "utilisation" here is an ambiguous concept: in the case of enhanced oil recovery, CO2 is simultaneously utilised and stored. But in many other utilisations, the CO2 would not be stored. I would suggest using more systematically the abbreviation CCS, or specify utilisation of CO2, rather than using "CCUS". Appropriate references could be Tanzer E. and A. Ramirez, 2019, When are negative emissions negative emissions? Energy Environ. Sci., , DOI: 10.1039/C8EE03338B, referred to on p.42; and Müller L.J. et alii, 2020, A Guideline for Life Cycle Assessment of Carbon Capture and Utilization, Frontiers in Energy Research,	Accepted. We have addressed this throughout the text.	Cédric PHILIBERT	Institut Français des Relations Internationales	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
76309	5	6	5	6	Here CCUS is synonymous with CCS (Bioenergy with CCS => BECCS), so it should be modified and CCU should be cited distinctly. CSS and Carbon Capture and Use (CCU) distinctly differ regarding their CO2 reduction potential, the underlying technical processes and outcomes, their effects on climate mitigation, their business models and their environmental policy targets. Therefore, presenting commingling CCS and CCU does not do justice to the specific characteristics of the two concepts and could be counterproductive for the further development particularly of CCU. Therefore the term CCUS should be separated in CCS and CCU and both options should be clearly addressed independently (Cuéllar-Franca and Azapagic, 2015, Bruhn et al., 2016, Arning et al., 2019). Please note that the definition formerly given of CCUS in the glossary (If the CO2 is stored in a product for a climate-relevant time horizon, this is referred to as CO2 capture, utilisation and storage (CCUS)) is not correct and is incoherent with the use of the term CCUS in the report as in most cases CCUS is used in the context of Carbon Capture and (geological) Storage. The high level report of the Science Advice for Policy by European Academies (SAPEA) has explicitily said: “measures, regulations and incentives should examine CCU in a holistic, integrated, coordinated and transparent manner » (SAPEA, 2018).•SAPEA, 2018, Science Advice for Policy by EU Academies, Novel Carbon Capture and Utilisation Technologies-Research and Climate Aspects, Evidence Review Report, 2.•Arning et al. 2019, Energy Policy, 125, 235–249.•Bruhn et al., 2016, Environmental Science & Policy, 60, 38–43.•Cuéllar-Franca and Azapagic, 2015, J.CO2.Utili., 9, 82-102.	Accepted. We have addressed this throughout the text.	Deepak PANT	Flemish Institute for Technological Research (VITO)	Belgium
78575	5	6	5	6	the wording 'CCUS' is highly misleading and shall be split to 'CCU' and 'CCS'. Both concepts are highly different, and it is increasingly found in research that they are applied in a strongly opposed manner: CCU corresponds with Power-to-X and low-cost renewable electricity, while CCS is linked to fossil fuel use and the implicit assumption/input of high-cost renewable electricity. More can be found in Breyer et al. (https://www.cell.com/joule/fulltext/S2542-4351(19)30413-1) and Bruhn et al. (https://www.sciencedirect.com/science/article/pii/S1462901116300508)	Accepted. We have addressed this throughout the text.	Christian Breyer	LUT University	Finland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
83693	5	6	5	6	Here CCUS means CCS (Bioenergy with CCS => BECCS), so it should be modified and CCU should be cited distinctly. CSS and Carbon Capture and Use (CCU) distinctly differ regarding their CO2 reduction potential, the underlying technical processes and outcomes, their effects on climate mitigation, their business models and their environmental policy targets. Therefore, presenting commingling CCS and CCU does not do justice to the specific characteristics of the two concepts and could be counterproductive for the further development particularly of CCU. Therefore the term CCUS should be separated in CCS and CCU and both options should be clearly addressed independently (Cuéllar-Franca and Azapagic, 2015, Bruhn et al., 2016, Arning et al., 2019). Please note that the definition formerly given of CCUS in the glossary (If the CO2 is stored in a product for a climate-relevant time horizon, this is referred to as CO2 capture, utilisation and storage (CCUS)) is not correct and is incoherent with the use of the term CCUS in the report as in most cases CCUS is used in the context of Carbon Capture and (geological) Storage. The high level report of the Science Advice for Policy by European Academies (SAPEA) has explicitily said: " measures, regulations and incentives should examine CCU in a holistic, integrated, coordinated and transparent manner » (SAPEA, 2018).•SAPEA, 2018, Science Advice for Policy by EU Academies, Novel Carbon Capture and Utilisation Technologies-Research and Climate Aspects, Evidence Review Report, 2.•Arning et al. 2019, Energy Policy, 125, 235–249.•Bruhn et al., 2016, Environmental Science & Policy, 60, 38–43.•Cuéllar-Franca and Azapagic, 2015, J.CO2.Utili., 9, 82-102.	Accepted. We have addressed this throughout the text.	Christian Breyer	LUT University	Finland
743	5	7		28	next generation conversion processes are not yet cost-effective? But why they are not cost-effective? The IEA thinks differently. It would be 27% in global transportation fuel by 2050. So, it is going up from 2% to 27%	Taken into Account. The paragraph has been revised and the issue is no longer relevant.	Alok Dhaundiyal	Szent Istvan University	Hungary
1745	5	8	5	16	The statement is demonstrably wrong. The counterexample is Australia - an industrialised, high energy consuming country that has no connection to other countries. Australia is installing solar PV and wind at a combined per capita rate that is 10X the global average and 4X Japan, China, USA and Europe (A. Blakers, M. Stocks, B. Lu, C. Cheng and R. Stocks, "Pathway to 100% Renewable Electricity," IEEE Journal of Photovoltaics, vol. 9, no. 6, pp. 1828-1833, 2019, https://ieeexplore.ieee.org/document/8836526). Detailed analysis shows that the Australian electricity system can reach 100% at low cost (Andrew Blakers, Bin Lu, Matthew Stocks, '100% renewable electricity in Australia', Energy, vol. 133, pp. 471-482, 2017, http://www.sciencedirect.com/science/article/pii/S0360544217309568).	Noted: This comment seems to be supportive of the statement that 10.Electricity systems powered predominantly by renewables will be increasingly viable over the coming decades.	Andrew Blakers	Australian National University	Australia

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
1747	5	8	5	16	The state of South Australia has a population of 1.7 million people. South Australia is currently generating 70% of its electricity from wind and solar (6-month moving average). The balance is generated from fossil gas with a small fraction (~1%) of net imports/exports. South Australia has no hydroelectric, coal, bio or nuclear generation. Recently, South Australia derived more than 100% of its electricity load from each of PV alone and wind alone for one hour. Combined PV and wind regularly exceeds 100% of the load for whole calendar days (midnight to midnight) with the excess being exported to other states. These landmarks will be quickly surpassed because deployment of PV and wind continues in South Australia. South Australia is tracking towards 100% PV/wind electricity in 2025. South Australia is part of the National Energy Market but is relatively weakly connected to other states. Transmission capacity to and from other states amounts to about 0.9 GW from the combined Heywood and Murraylink interconnectors compared with average and peak demand of 1.6 GW and 3.2 GW respectively. In 2020, exports of electricity to neighbouring states were 8% and were nearly balanced by imports (7%). South Australia hosts about 0.3 GW of batteries with about one hour of storage, and this is expected to increase. Shortfalls in solar and wind generation compared with demand are met using batteries, fossil gas generators and imported electricity.	Noted: This comment seems to be supportive of the statement that 10.Electricity systems powered predominantly by renewables will be increasingly viable over the coming decades.	Andrew Blakers	Australian National University	Australia
1749	5	8	5	16	Currently, about 30% of National Electricity Market electricity comes from renewables (about 12% each of PV and wind and 6% from hydro). Black coal, brown coal (lignite) and gas provides the balance. Renewable generation regularly exceeds 50% during the day. PV and wind alone regularly exceed 30% of the load for whole calendar days (midnight to midnight). These landmarks will be quickly surpassed because deployment of PV and wind continues in Australia.	Noted: This comment seems to be supportive of the statement that 10.Electricity systems powered predominantly by renewables will be increasingly viable over the coming decades.	Andrew Blakers	Australian National University	Australia
1751	5	8	5	16	Wholesale electricity prices in both the National Electricity Market and in South Australia are below US$40/MWh (https://opennem.org.au/energy/nem/?range=7d&interval=30m). This demonstrates that PV/wind and the associated balancing costs are modest. Facts on the ground should beat any model.	Noted: This comment seems to be supportive of the statement that 10.Electricity systems powered predominantly by renewables will be increasingly viable over the coming decades.	Andrew Blakers	Australian National University	Australia
15823	5	8	5	16	"Electricity systems powered predominantly by renewables will be increasingly viable over the coming decades, but it will be challenging supply the entire energy system entirely with renewables (high confidence).": this point is rightly highlighted. "Research increasingly indicates that large shares of variable solar PV and wind power can be incorporated in electricity grids through batteries, other forms of storage, broader transmission systems, advanced controls, and greater demand side responses (high confidence).": this latter statement seems, in contrast, at odds with the analysis of chapter 6 pages 82-86. Batteries are not yet seen as the general storage technology for 2050. Decarbonised and dispatchable generating technologies are still considered inescapable and contribute to a least cost strategy to support the development of variable renewables.	Taken into Account: We have added flexible non-renewable to the list	Jean-Michel Trochet	EDF group (French Utility)	France
17311	5	8	5	9	"Electricity systems powered predominantly by renewables will be increasingly viable over the coming decades..." I would not put high confidence on that. Examples from the most developed countries/states in the World: Germany (Energiewende), California (Fall heat wave 2020), Texas (Winter storm 2020/21) do not support these statements.	Reject: The literature is suggesting that they will be increasingly viable. Predominantly does not mean 100%	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
29555	5	8	5	16	Please consider mentioning the challenges for grid stability of including large shares of intermittent power. Source of information could be the UK Department for Business, Energy and Industrial Strategy (BEIS) report on Electricity Generation Costs 2020 (Source:https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/911817/electricity-generation-cost-report-2020.pdf)	Noted: we state operational challenges increase with higher shares of renewable electricity and energy. Because of space constraints, we cannot name all of those challenges.	Government of Norway	Norwegian Environment Agency	Norway
51025	5	8	5	9	"Electricity systems powered predominantly by renewables will be increasingly viable in the coming decades": once more, such a formulation -"increasingly viable"- should is proscribed from this report; it opens to all sorts of interpretations and therefore is misleading. Especially when what is meant by viable is not defined and when the temporal horizon itself is quite vague ("in the coming decades" just can means anytime between 15 years and 99 years. Also, "predominantly powered" is pretty fuzzy too. Consider reformulating.	Reject: We do not have space in this ES to specify all the characteristics underpinning the meaning of "viable".	Eric PROUST	European Nuclear Society (ENS)	France
61575	5	8	5	16	The highlighted conclusion combines two important conclusions: one on the fact that high penetration of renewables will be more feasible at the grid level in the future and the other on the challenge to shift the entire energy system to electricity. It is recommended to seperate these conclusions since they are both significant and combining them reduces the significance of both.	Reject: We believe that it's useful to put them together because there is confusion between them.	Kent Buchanan	Department of Environmental Forestry and Fisheries	South Africa
61747	5	8	5	16	If there exists high confidence in that "[e]conomic, regulatory, and operational challenges increase with higher shares [of wind and solar], and the ability to overcome these is not fully understood", how can there be only medium confidence in that "100% renewable energy systems [are]more difficult to attain"? This should rephrased to high confidence. Further, there is no real-world evidence of such a thing happening outside special cases such as Norway (hydro resource) and Iceland (geothermal resource). Most models have been lacking in their evaluation of 100% renewable electricity (not energy) systems, so we have no idea even in models if such high shares of renewable energy are feasible. Further, 100% renewable is not a goal, but a “100% low carbon” is, so why should it even be mentioned?	Taken into Account: The text has been revised so that all statements have high confidence.	Rauli Partanen	Think Atom	Finland
65779	5	8	5	16	If there exists high confidence in that "[e]conomic, regulatory, and operational challenges increase with higher shares [of wind and solar], and the ability to overcome these is not fully understood", how can there be only medium confidence in that "100% renewable energy systems [are] more difficult to attain"? This should rephrased to 'high confidence'.	Taken into Account: The text has been revised so that all statements have high confidence.	Eero Hirvijoki	Aalto University	Finland
69453	5	8	5	16	This paragraph is juxtaposing two types of issues relating to the challenge of supplying the entire energy system with renewables. The first is the variability of solar PV and wind power and its incorporation in electricity grid. The second is the presence of hard to decarbonise sectors (deep sea shipping should be mentioned here). However, this paragraph fails to show how some of the difficulties of decarbonisation may paradoxically facilitate the integration of variable renewable in the electric systems. Not only batteries of electric vehicles, but power-to-heat for industry coupled with heat storage, air-conditionning systems integrating cold storage, and eletrolysers to deliver hydrogen-based feedstocks and fuels can be made interruptible at times of electricity demand peaks or low solar and wind production (or both). In that, they will help finance a further extension of renewables while not adding to the net demand peaks, and, to the opposite, reduce the volume of controllable electricity needed to ensure electricity security.	Noted: The text already includes sector coupling in the list of integration approaches under "greater demand side responses."	Cédric PHILIBERT	Institut Français des Relations Internationales	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
73937	5	8	5	10	This sentence is confusing. "to" is missing before "supply". The expression "entire energy system entirely" could be simplified .	Taken into Account: This sentence was rephrased.	Heleno Miguel	Lawrence Berkeley National Laboratory	United States of America
74857	5	8	5	16	Grid integration challenges are a limitation to Solar PV and wind deployment. Currnetly Geothermal energy is being curtailed and steam being vented especially during off peak hours to dispatch wind and solar. This is because commitemnts are on take or pay contracts	Noted: This bullet already mentions grid integration challlenges from variable renewables, and the comment seems supportive.	Government of Kenya	Kenya Meteorological Service	Kenya
78493	5	8	5	9	"Electricity systems powered predominantly by renewables will be increasingly viable over the coming decades..." I would not put high confidence on that. Examples from the most developed countries/states in the World: Germany (Energiewende), California (Fall heat wave 2020), Texas (Winter storm 2020/21) do not support these statements. Replace this statement with "Electricity systems powered by renewables and nuclear will be increasingly common." Sweden, France, Ontario are examples of reliable, low carbon systems running on hydro and nuclear.	Noted: This comment seems to be supportive of the statement that 10.Electricity systems powered predominantly by renewables will be increasingly viable over the coming decades.	Tomaž Žagar	Faculty for Energy Technology, University of Maribor	Slovenia
82283	5	8	5	16	The title is misleading! You conclude that "medium confidence" to difficult to make 100% renewable energy system. What you in the text conclude as high confidence is to have the electricity system powered by high share of intermittent renewables. Suggestion: Either re-write title, or add the word "intermittent" to the last renewable: "…………..with intermittent renewables (high confidence)."	Taken into Account: The text has been revised so that all statements have high confidence. We also rephrase "intermittent" as "variable" (to maintain consistency with other chapters).	Anna Krook-Riekkola	Luleå University of Technology	Sweden
84373	5	8	5	16	One concern should be stated about the energy cost spent for advanced control of a diluted and variable power system under the ICT current CMOS technology (thermodynamic efficiency around 10^-8). In other words, a significant technical change in ICT should be achieved in order to consider management of low carbon energy system.	Reject: The bullet already discusses economic challenges of high renewables systems, and space constraints prevent us from discussing in greater detail in the summary points.	Vincent MAZAURIC	Schneider Electric	France
735	5	9			'to' is missing before supply (rewrite the sentence but it will be challenging supply the entire energy system entirely with..) renewable sources ?	Taken into Account: This sentence was rephrased.	Alok Dhaundiyal	Szent Istvan University	Hungary
7843	5	9	5	9	but it will be challenging supply' should be 'but it will be challenging to supply'	Taken into Account: This sentence was rephrased.	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
10629	5	9	5	9	insert "to" in front of "supply"	Taken into Account: This sentence was rephrased.	Philippe Waldteufel	CNRS	France
43529	5	9	5	9	Insert "to" between "challenging" and "supply"	Taken into Account: This sentence was rephrased.	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy
49751	5	9	5	10	'but it will be…….. renewable' – this sentence needs suitable correction	Taken into Account: This sentence was rephrased.	PINAKI SARKAR	CSIR-CIMFR, Dhanbad	India
51027	5	9	5	10	"it will be challenging supply the entire energy system entirely with renewables". This statement being too much of an understatement, is misleading. Consider adding "extremely" ("it will be extremely challenging"). It is only for the very few countries which have a large hydropower potential that this will not be the case in a forseeable future.	Rejected: This additional modifier does not seem warrented on the basis of the review later in the chapter.	Eric PROUST	European Nuclear Society (ENS)	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
74839	5	9	5	20	In line 9, it should read challenging to supply,,,,, In line 19 and 20, Sentence is incomplete "becoming competitive in others????,	Taken into Account: These sentences were rephrased.	Government of Kenya	Kenya Meteorological Service	Kenya
85323	5	9	5	9	mission TO - challenging TO supply the entire energy system	Taken into Account: This sentence was rephrased.	Linda Hancock	Deakin University	Australia
28357	5	10	5	14	The statement "Economic, regulatory, and operational challenges increase with higher shares, and the ability to overcome these is not fully understood (high confidence)." needs an addition about positive role of other low carbon energy sources in the energy mix. I suggest the following revision "Economic, regulatory, and operational challenges increase with higher shares, and the ability to overcome these is not fully understood. Keeping significant shares of dispatchable low carbon energy sources, such as Hydro and Nuclear, in the energy mix (at least for a certain time necessary for evolutionary developments) allow to reach the targeted net-zero CO2 with a reduced risk of a mistakes in energy policy (high confidence)."	Taken into Account: "flexible non-renewable generation" was added to the list.	Sevostian Bechta	KTH-Royal Institute of Technology	Sweden
42961	5	10	5	12	Is "broader" transmission system the intent. I suggest the term inter-connected transmission systems, which is the common industry term for moving energy from one balancing authority to another.	Taken into Account: This was rephrased simply as "transmission."	Kurt Kornelsen	Ontario Power Generation	Canada
42963	5	10	5	12	Why are batteries identified specifically alongside "other forms of storage". Should this not just be energy storage as all encompassing which would also embrace new forms of storage technology?	Rejected: The earlier bullet discusses cost reductions for batteries, hence including that here.	Kurt Kornelsen	Ontario Power Generation	Canada
51029	5	10	5	12	"Research increasingly indicates that large shares of variable solar PV and wind power can be incorporated in electricity grids through batteries, other forms of storage, broader transmission systems, advanced controls, and greater demand side responses (high confidence)": This statement is misleading. Indeed, Ok, technically, this is possible even with the technology available today (you don't need research, you just need to produce and install huge capacities of batteries It is economically not feasible, but it is technically). Writing that this observation is the fruit of research and adding the tag "high confidence" let the reader think that there is more than just a theoretical technical feasibility here, that economic viability is taken into account. Therefore, It should be explicitely stated that this statement is a purely technical consideration.	Rejected: A subsequent sentence mentions economic, operational, and other challenges and notes that these challenges come "in practice".	Eric PROUST	European Nuclear Society (ENS)	France
76571	5	10	5	12	other forms of energy storage should be named as well (f.e. pump storage)	Rejected: The earlier bullet discusses cost reductions for batteries, hence including that here.	Armin Winkler	University of Applied Sciences Upper Austria	Austria
77327	5	10	5	11	Reservoir hydropower and pumped storge hydropower represent the by far largest low-carbon technology for electricity storage at multiple time scales, and will continue to do so even with an enormous deployment of batteries. It is important to focus on the major role hydropower is playing today and the potential for this in the future. Please change sentence to incorporate this: "Research increasingly indicates that large shares of variable solar PV and wind power can be incorporated in electricity grids through integration of reservoir and pumped storage hydropower, batteries, other forms of storage,...."	Rejected: The earlier bullet discusses cost reductions for batteries, hence including that here.	Atle Harby	SINTEF Energy Research	Norway
28937	5	11	5	11	I propose to add for clarity: through batteries, other forms of electrical, mechanical or chemical storage	Rejected: Space constraints prevent us from elongating this sentence.	Fabian Heymann	INESC TEC	Switzerland
737	5	12			greater demand-side responses 'add hyphen'	Taken into Account: A hyphen was added.	Alok Dhaundiyal	Szent Istvan University	Hungary

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
51031	5	12	5	12	“and greater demand side responses”: Right, this term "responses" is preferred because it is more "consumer-friendly". I nevertheless suggest replacing “reponses” by “management” which is a more appropriate / self-understanding term here and in the many other sentences in this chapter which use this formulation.	Rejected: "responses" aligns better with the text elsewhere in the chapter.	Eric PROUST	European Nuclear Society (ENS)	France
51033	5	13	5	14	“Economic, regulatory, and operational challenges increase with higher shares, and the ability to overcome these is not fully understood (high confidence).”This statement should be complemented by a mention about the positive role of low-carbon dispachable energy sources in the energy mix to minimize the need for very high shares of renewables and thus the associated challenges. Consider revising as follows “Economic, regulatory, and operational challenges increase with higher shares, and the ability to overcome these is not fully understood. Until full understanding and these challenges overcome, maintaining a significant share of low carbon dispachable energy sources, such as hydropower and nuclear, in the electricity mix can enable its full decarbonisation (high confidence).”	Taken into Account: "flexible non-renewable generation" was added to the earlier list.	Eric PROUST	European Nuclear Society (ENS)	France
55585	5	13	5	14	Statement is not accurate as there is ample knowledge today for economic, regulatory, and operations with relatively high shares of VRE/non-sychronous generation (Ireland, Australia).	Taken into Account: "in practice" was added to this sentence.	Government of United States of America	U.S. Department of State	United States of America
71517	5	13	5	14	It is correct that some things regarding fully renewable electricity systems are not yet fully understood. However, I am not sure whether this should be mentioned this prominently. I would at least add at a sentence stating that technically, a fully renewable system is possible and challenges depend on the locational specifics.	Rejected: Space constraints prevent us from elongating this sentence.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
9145	5	14	5	16	and shipping,also difficult decarbonize	Taken into Account: This list was removed.	Marin Constantin	RATEN ICN	Romania
20873	5	14	5	14	Shipping could also be added in the high-emiter sectors hard to decarbonize	Taken into Account: This list was removed.	Government of France	Ministère de la Transition écologique et solidaire	France
30701	5	14	5	15	As an example of a sector that is difficult to decarbonize, the industrial sector is listed as a whole, while the transportation sector is taken out only in the aviation sector. It would be better to have a well-balanced description, such as subdividing the industrial sector.	Taken into Account: This list was removed.	Government of Japan	Climate Change Division - Ministry of Foreign Affairs	Japan
51035	5	14	5	16	“Beyond electricity, hard-to-decarbonise sectors, such as aviation, industry, and agriculture, will make 100% renewable energy systems more difficult to attain (medium confidence)”. It should read “even more difficult”: add “even”: 100% renewable electricity sytems will already be pretty difficult to attain	Taken into Account: The sentence was rewritten.	Eric PROUST	European Nuclear Society (ENS)	France
63111	5	15			Clarifying the term "industry" would be useful, e.g. petrochemicals, cement, steel, etc., since some industries are more easily decarbonized than others. If not noted elsewhere in the chapter, recognition of some advances in decarbonising these sectors should be noted here, as well.	Taken into Account: This list was removed.	Jennifer Sklarew	George Mason University	United States of America
739	5	17			Some energy options are available today.	Rejected: Not specific enough.	Alok Dhaundiyal	Szent Istvan University	Hungary
1695	5	17	5	28	Should the use of green hydrogen as an substitute of electricy be mentioned here? It seems more important in hare-to-decarbonise sectors and potentailly be use much more widely in the coming decades.	Rejected: We are focused here on supply options.	Taoyuan Wei	CICERO Center for International Climate Research	Norway

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
1753	5	17	5	28	Solar PV and wind have won the energy race. Everything else is small by comparison. They constitute 2/3 of global net new generation capacity additions. In pathfinder countries such as Australia they are 99% of capacity additions. Facts on the ground should trump models.	Noted: The paragraph has been substantially revised to limit discussion of the characteristics of specific options and simply to point out that many are available for near-term reductions.	Andrew Blakers	Australian National University	Australia
29877	5	17	5	28	Please consider to add "However, storage hydropower will most likely be essential to balance an renewable electricity marked in many regions as one of the most flexible renewable energy resources, and hence may be stored/produced as an imprtant supplement to intermittent electricity from solar, wind or run-of-river hydropower	Noted: The paragraph has been substantially revised to limit discussion of the characteristics of specific options and simply to point out that many are available for near-term reductions.	Government of Norway	Norwegian Environment Agency	Norway
51041	5	17	5	28	This paragraph should also cover electricity/energy storage	Rejected: We are focused here on supply options.	Eric PROUST	European Nuclear Society (ENS)	France
63617	5	17	5	28	In this section, modern bioenergy should be acknowleged as a competetive near term mitigation option. Modern bioenergy includes efficient use of biomass for district heating, combined heat and power and industrial thermal energy, for example, and makes up about 50% of renewable energy consumption. IEA (2020), SDG7: Data and Projections, IEA, Paris https://www.iea.org/reports/sdg7-data-and-projections	Noted: The paragraph has been substantially revised to limit discussion of the characteristics of specific options and simply to point out that many are available for near-term reductions.	Government of Canada	Environment and Climate Change Canada	Canada
64229	5	17	5	22	Sorry - the so-called “poor economic viability of nuclear power” is a wrong statement. New nuclear power will remain the dispatchable low-carbon technology with the lowest expected costs in 2025, according to the 2020 edition of the IEA Projected Costs of Generating Electricity. It is the ninth report in the series on the levelised costs of electricity (LCOE) jointly prepared every five years by the International Energy (IEA) and the OECD Nuclear Energy Agency (NEA). The report also finds that prolonging the operation of existing nuclear power plants, known as long-term operation (LTO), is the most cost-effective source of low carbon electricity. Hydroelectric power can provide a similar contribution at comparable costs, however remains highly dependent on the natural endowments of individual countries. NB - for the first time the report also presents a new complementary metric, the “value-adjusted” LCOE (VALCOE) measure in order to account for the increasing importance of system considerations within the context of the growing share of variable renewable energy (VRE) technologies. Source : « Low-carbon generation is becoming cost competitive, IEA and NEA say in new report” - https://www.oecd-nea.org/jcms/pl_51126/low-carbon-generation-is-becoming-cost-competitive-nea-and-iea-say-in-new-report * IEA and NEA - Full report “Projected Costs of Generating Electricity 2020 — December 2020 » - https://www.iea.org/reports/projected-costs-of-generating-electricity-2020	Noted: The paragraph has been substantially revised to limit discussion of the characteristics of specific options and simply to point out that many are available for near-term reductions.	Georges VAN GOETHEM	Royal Academy of Overseas Sciences (ARSOM - KAOW)	Belgium

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
17313	5	18	5	22	"Solar PV and wind power are already cheaper than fossil electricity in many locations and are becoming competitive in others. Nuclear power is economically viable in some circumstances, but public and political support, along with improved construction management and reactor designs to lower costs, will be important to allow its broader use." I cannot agree: the key problem of the Chapter 6 again: discussing large-scale solar and wind price without storage and huge modifications of the electric systems is not acceptable. On the other side LCOE price of nuclear is indeed higher than wind, solar PV or hydro, but does not require storage costs. US EIA solves this problem in their Annual Energy Outlook documents by separating electricity sources into dispatchable (nuclear) and non-dispatchable (wind, solar).	Noted: The paragraph has been substantially revised to limit discussion of the characteristics of specific options and simply to point out that many are available for near-term reductions.	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
43749	5	18	5	20	Please specify as this is a crucial information for current investment decisions. What does "becoming competitive" refer to? What is the associated timescale? For which locations does this apply?	Rejected. Self explanatory. Because of space constraints, we are limited in the precision by which we can define all of our statements.	Government of Jamaica	Meteorological Service Division	Jamaica
50187	5	18	5	20	This information is very relevant for investment decisions in the coming years, but is not sufficiently precise. Which factors does the competitiveness depend on? What does this translate to for remote regions in particular?	Rejected. Self explanatory. Because of space constraints, we are limited in the precision by which we can define all of our statements.	Anna Main	Ministry of Foreign Affairs and Trade	Samoa
51037	5	18	5	20	"Solar PV and wind power are already cheaper than fossil electricity in many locations and are becoming competitive in others": this statement is both inaccurate and misleading. Indeed, to compare a technology which provides a service the reader is accustomed to with another one which provides a lower-value service, and to do this without stressing the difference in the services provided, is ... how to say that? let's keep it to ''misleading''. Obviously, if you need electricity at night, solar PV electricity is considerably less competitive than fossil electricity. The same holds for wind power if you need electricity during the ~75% of the time when wind turbines cannot produce electricty due to lack of enough wind. Reformulation is necessary. I suggest adding something like "if you do not take into account the cost of the means needed to compensate for their intermittence (solar) or variability (wind)"	Noted: The paragraph has been substantially revised to limit discussion of the characteristics of specific options and simply to point out that many are available for near-term reductions.	Eric PROUST	European Nuclear Society (ENS)	France
77195	5	18	5	20	It could be fair to maintain the simmetry potential/challenge for all sources, including PV and wind. Something like ", but for a massive deployment a further reduction of the overall costs of electric system transformation will be requested" could be added at the end of the sentence.	Noted: The paragraph has been substantially revised to limit discussion of the characteristics of specific options and simply to point out that many are available for near-term reductions.	Giacomo Grasso	ENEA	Italy
81883	5	18	5	20	This information is very relevant for investment decisions in the coming years, but is not sufficiently precise. Which factors does the competitiveness depend on? What does this translate to for remote regions in particular?	Rejected. Self explanatory. Because of space constraints, we are limited in the precision by which we can define all of our statements.	Francella Strickland	Ministry of Foreign Affairs and Trade	Samoa
43531	5	19	5	19	There is no such theing as fossil electricity. Replace with "fossil-fuel-based electricity"	Noted: The paragraph has been substantially revised to limit discussion of the characteristics of specific options and simply to point out that many are available for near-term reductions.	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
8913	5	20	5	22	I propose "Nuclear power is economically viable in many parts of the world (eg. Asia), but is still in a complex situation in Europe. In this continent, it needs both public and political support, along with improved construction management and reactor designs to lower costs". See OECD/IEA (2020), "Nuclear power", in Tracking Clean Energy Progress, IEA, Paris, https://www.iea.org/reports/nuclear-power IEA and NEA and OECD (2020) " Projected Costs of Generating Electricity: 2020 Update" International Energy Agency (IEA) and Nuclear Energy Agency (OECD/NEA) Paris: OECD https://www.oecd-nea.org/jcms/pl_51110/projected-costs-of-generating-electricity-2020-edition	Noted: The paragraph has been substantially revised to limit discussion of the characteristics of specific options and simply to point out that many are available for near-term reductions.	Jean-Guy DEVEZEAUX DE LAVERGNE	Université Paris-Dauphine & Société Française d'Energie Nucléaire	France
33045	5	20	5	20	disagree with using and developing nuclear power plants as they are too risky in terms of safety, specially when it goes to the developing countries.	Noted: The paragraph has been substantially revised to limit discussion of the characteristics of specific options and simply to point out that many are available for near-term reductions.	Yashar Hajimolana	University of Twente	Netherlands
63619	5	20	5	22	We suggest adding a sentence after "will be important to allow its broader use." based on the IEA Projected Costs of Generating Electricity 2020 Edition (https://www.iea.org/reports/projected-costs-of-generating-electricity-2020) where it is mentioned that SMRs are proposing to address these risks through modularization, design simplification, standardization and passive safety systems. At the end of this paragraph we also suggest adding a sentence about how the cost of electricity cannot be based upon plant level economics only, but must take into consideration system level costs as well. Therefore competitiveness is also conditional on the specific country and region grid which is also discussed in the IEA Projected Costs of Generating Electricity 2020 edition.	Noted: The paragraph has been substantially revised to limit discussion of the characteristics of specific options and simply to point out that many are available for near-term reductions.	Government of Canada	Environment and Climate Change Canada	Canada
76577	5	20	5	22	Nuclear power should not be in focus in this report because of the high risk and the unanswerd questions concerning disposal and storage of radioactive waste.	Noted: The paragraph has been substantially revised to limit discussion of the characteristics of specific options and simply to point out that many are available for near-term reductions.	Armin Winkler	University of Applied Sciences Upper Austria	Austria
76607	5	20	5	22	This sentence is policy prescriptive	Noted: The paragraph has been substantially revised to limit discussion of the characteristics of specific options and simply to point out that many are available for near-term reductions.	Charlotte MIJEON	Réseau "Sortir du nucléaire" (organizsation affiliated to the French Climate Action Network)	France
77197	5	20	5	22	If the proposal introduced in comment 14 above is rejected, the initial statement "Nuclear power is economically viable in some circumstances" should be changed into "Nuclear power, the second major contributor of low-carbon electricity globally, is economically viable in some circumstances".	Noted: The paragraph has been substantially revised to limit discussion of the characteristics of specific options and simply to point out that many are available for near-term reductions.	Giacomo Grasso	ENEA	Italy
77199	5	20	5	22	Cost is not a factor limiting broader use of nuclear. The higher costs are observed for some first-of-a-kind projects, which are not representative of the follow-on units. Notwithstanding, even those high costs project a cost of electricity that is far lower than for many other sources. All this clarified, repeating here "improved construction management and reactor design to lower costs", which were meant as the factors determining the "circumstances" under which nuclear could not be economically viable, is a unuseful repetition, not adding to the actual limiting factor which is the public support.	Noted: The paragraph has been substantially revised to limit discussion of the characteristics of specific options and simply to point out that many are available for near-term reductions.	Giacomo Grasso	ENEA	Italy

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
78577	5	20	5	22	the claim that nuclear would be economic viable violates real world facts and requires adjustment. Nuclear power is the highest cost form of all major electricity options for new builts, as documented by new construction sites in Europe, the US and elsewhere. This is well documented in reports and articles for various researchers and institutions. IPCC authors better accept this market facts which are in strong violation to the statement. This has been even documented in the WEO 2020 of the IEA see Tables B.2a/b, the Lazard reports (https://www.lazard.com/media/451419/lazards-levelized-cost-of-energy-version-140.pdf), and scientific literature, such as Ram et al. (https://www.sciencedirect.com/science/article/pii/S0959652618321486).	Noted: The paragraph has been substantially revised to limit discussion of the characteristics of specific options and simply to point out that many are available for near-term reductions.	Christian Breyer	LUT University	Finland
79705	5	20			There is actually a large difference between countries with regards to public opinion: in some countries public opinion supports nuclear, in other it does not. See two surveys: 1/ https://www.edf.fr/sites/default/files/contrib/groupe-edf/obs-climat/2020/obscop2020_resultatscomplets_en.pdf 2/ https://www.ipsos.com/sites/default/files/publication/1970-01/ipsos-sri-after-fukushima-march-2012.pdf	Noted: The paragraph has been substantially revised to limit discussion of the characteristics of specific options and simply to point out that many are available for near-term reductions.	valerie faudon	SFEN	France
81911	5	20	5	21	There seem to be hardly any nuclear plants that have been built without high government subsidies and the statement that nuclear power is economically viable in some circumstances does not seem substantiated, in particualr not if the costs of nuclear waste disposal are included in hte economic assessment of nuclear power plants. This statement is not substantiated here or in section 6.4.2.4 with scientific references. Recent nuclear projects in China for which no transparent and indipendent cost studies are likely to be availbale are not considered as sufficient proof for this statement.	Noted: The paragraph has been substantially revised to limit discussion of the characteristics of specific options and simply to point out that many are available for near-term reductions.	Anke Herold	Oeko-Institut e.V.	Germany
63113	5	21			Nuclear waste management solutions should be added here	Noted: The paragraph has been substantially revised to limit discussion of the characteristics of specific options and simply to point out that many are available for near-term reductions.	Jennifer Sklarew	George Mason University	United States of America
18209	5	22	5	24	Add a point about land use competition here? V important to consider in biofuels as well as crops performance https://bit.ly/3jDYFMb	Noted: The paragraph has been substantially revised to limit discussion of the characteristics of specific options and simply to point out that many are available for near-term reductions.	Government of United Kingdom (of Great Britain and Northern Ireland)	Department for Business, Energy & Industrial Strategy	United Kingdom (of Great Britain and Northern Ireland)
48003	5	22	5	24	Biofuels are already cost-effective in many countries and regions (e.g. Brazil, EU, the U.S.). This statement in lines 22-23 seems to simply ignore and discard biofuels currently used for land transportation, even though in many countries they play a key role - and are expected to keep playing that role at least in the near- to mid-term - in reducing GHG emissions of the transport sector. Since near-term ambition is so important, why ignore such an important mitigation option for many countries? In fact, in a different section of this Chapter 6 (p. 43, l. 34-38), it is recognized that ethanol would currently be comparable to gasoline. This should be corrected. The following alternative wording is therefore proposed: "Biofuels hold the promise of broadly supplanting fossil fuels in some applications, but, while conventional technologies may already be cost-effective, that is not yet the case for next generation conversion processes [...]" It should be noted that a similar paragraph was included in the Technical Summary (p. 50, l.23-24) and should be reviewed accordingly.	Noted: The paragraph has been substantially revised to limit discussion of the characteristics of specific options and simply to point out that many are available for near-term reductions.	Marcelo moreira	UNICAMP - Agroicone	Brazil

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
50923	5	22	5	24	Biofuels are already cost-effective in many countries and regions (e.g. Brazil, EU, the U.S.). This statement in lines 22-23 seems to simply ignore and discard biofuels currently used for land transportation, even though in many countries they play a key role - and are expected to keep playing that role at least in the near- to mid-term - in reducing GHG emissions of the transport sector. Since near-term ambition is so important, why ignore such an important mitigation option for many countries? In fact, in a different section of this Chapter 6 (p. 43, l. 34-38), it is recognized that ethanol would currently be comparable to gasoline. This should be corrected. The following alternative wording is therefore proposed: "Biofuels hold the promise of broadly supplanting fossil fuels in some applications, but, while conventional technologies may already be cost-effective, that is not yet the case for next generation conversion processes [...]" It should be noted that a similar paragraph was included in the Technical Summary (p. 50, l.23-24) and should be reviewed accordingly.	Noted: The paragraph has been substantially revised to limit discussion of the characteristics of specific options and simply to point out that many are available for near-term reductions.	Government of Brazil	Ministry of Foreign Affairs of Brazil	Brazil
86605	5	22		24	"Biofuels hold the promise of broadly supplanting fossil fuels in some applications". There needs to be an assessment of biofuel resources acros all sectors. Biofuels or synthetic fuels are seen as promising for freight, aviation and shipping and industry and has a more important role in the harder to decarbonise sectors. Costs or prices will be more sensitive in some sectors than others. Without a cross cutting analysis there is a risk of double counting the resouce.	Noted: The paragraph has been substantially revised to limit discussion of the characteristics of specific options and simply to point out that many are available for near-term reductions.	Mark Hinnells	Ricardo Energy and Environment	United Kingdom (of Great Britain and Northern Ireland)
741	5	23			the next-generation 'add hyphen'	Noted: The paragraph has been substantially revised to limit discussion of the characteristics of specific options and simply to point out that many are available for near-term reductions.	Alok Dhaundiyal	Szent Istvan University	Hungary
2625	5	24	5	26	I think that "will always cost more" is a overstatement. It almost reads as if there was a law of nature that prohibits CCUS to become cost competitive. I don't think there is such a law because the economic attractiveness of CCUS very much depends on how externalities are factored in and if the costs originating from unabated emissions exceed the cost premium of CCUS, then CCUS might well cost less than "a comparable process in which CO2 is not captured".	Noted: The paragraph has been substantially revised to limit discussion of the characteristics of specific options and simply to point out that many are available for near-term reductions.	Jan Wohland	ETH Zurich	Switzerland
20875	5	24	5	24	About "CCUS is technologically ready [...]", please consider the following question : But to what extent CO2 storage will be locally accepted by residents ?	Noted: The paragraph has been substantially revised to limit discussion of the characteristics of specific options and simply to point out that many are available for near-term reductions.	Government of France	Ministère de la Transition écologique et solidaire	France
51039	5	24	5	26	Public support will also be important to enable a broad use of CCS (the acceptability of CO2 storage by the local residents is an issue)	Noted: The paragraph has been substantially revised to limit discussion of the characteristics of specific options and simply to point out that many are available for near-term reductions.	Eric PROUST	European Nuclear Society (ENS)	France
63115	5	24			Reference to trade-offs with fodd production would be useful to mention here.	Noted: The paragraph has been substantially revised to limit discussion of the characteristics of specific options and simply to point out that many are available for near-term reductions.	Jennifer Sklarew	George Mason University	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
78001	5	24	5	26	Suggested edit: Replace sentence with: "Some forms of CCSU are technologically ready and profitable but strong public support will be essential to rapidly scale up markets for carbon neutral and negative fuels and building materials for timely climate restoration impact." Rationale: See other Baiman suggested edits for Chapter 6: Energy systems p. 38 lines 8-12.	Noted: The paragraph has been substantially revised to limit discussion of the characteristics of specific options and simply to point out that many are available for near-term reductions.	Ron Baiman	Benedictine University	United States of America
17849	5	25	5	25	CCUS has been deployed at a commercial-scale since 1972. There are 26 commercial CCUS projects operating. This is not demonstration stage. IEA shows that the main components of CCUS have reached commercial and mature stages in their TRL assessment. Reference: https://www.iea.org/reports/ccus-in-clean-energy-transitions/ccus-technology-innovation	Noted: The paragraph has been substantially revised to limit discussion of the characteristics of specific options and simply to point out that many are available for near-term reductions.	Eve Tamme	Global CCS Institute	Belgium
69455	5	25	5	26	As a textbook illustration of the confusion that CCUS can create this sentence opposes CCUS to "processes in which CO2 is not captured and stored" - hence CCS should be used here instead.	Noted: The paragraph has been substantially revised to limit discussion of the characteristics of specific options and simply to point out that many are available for near-term reductions.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
76573	5	26	5	28	There is a lot of potential for refurbishment of old hydro power plants and this should be in focus to tackle climate change. By replacing the turbine runners, renew turbine parts, implementing modern control systems a lot of improvement of old hydro power plants concerning efficiencies and operating ranges is possible.	Noted: The paragraph has been substantially revised to limit discussion of the characteristics of specific options and simply to point out that many are available for near-term reductions.	Armin Winkler	University of Applied Sciences Upper Austria	Austria
76579	5	26	5	28	The main advantage of hydroelectric power is that it can be regualted very easily and can be therefore used to stabilise the grid. This will be very important in future.	Noted: The paragraph has been substantially revised to limit discussion of the characteristics of specific options and simply to point out that many are available for near-term reductions.	Armin Winkler	University of Applied Sciences Upper Austria	Austria
77201	5	26	5	28	If the proposal introduced in comment 14 above is accepted, and all this block (lines 17 to 28) is moved to page 4, the incipit of this sentence shall be rephrased, e.g. "Hydroelectric power is the most economically viable option for low-carbon electricity, but ..." If instead the proposal above is rejected, the statement "to be a major source of electricity" should be changed into "to be the major source of low-carbon electricity".	Noted: The paragraph has been substantially revised to limit discussion of the characteristics of specific options and simply to point out that many are available for near-term reductions.	Giacomo Grasso	ENEA	Italy
77329	5	26	5	26	I don't think it is possible to document that the potential in increase in hydropower deployment is "modest" when considering environmental constraints. This will vary from site to site, and there are also many examples of "modest" potential for other technologies. We see that all renewable generation technologies, infrastructure, etc may have a large impact on nature and the environment, this is not only for hydropower - but also for wind and solar power (and all kinds of infrastructure, buildings etc that is needed in addition to the generating units). There are also other environmental and sustainability issues connected with low-carbon technologies (i.e. rare minerals extracted by children in Congo for batteries and wind turbines, water consumption in cleaning of solar PV plants, aqutic biodiversity impacts of hydropower, nuclear waste treatment etc). I suggest to write that all low-carbon technologies still have a large potential, but sustainability issues may limit the deployment in many sites.	Noted: The paragraph has been substantially revised to limit discussion of the characteristics of specific options and simply to point out that many are available for near-term reductions.	Atle Harby	SINTEF Energy Research	Norway

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
29879	5	27	5	28	Please consider highlighting "flexible" electricity, with a greater potential for pump-storage. A considerable unutilised potential for sustainable hydropower development and operation are still realistic in many countries, particularly in Africa, Asia and parts of America.	Noted: The paragraph has been substantially revised to limit discussion of the characteristics of specific options and simply to point out that many are available for near-term reductions.	Government of Norway	Norwegian Environment Agency	Norway
42965	5	27	5	27	The term "potential for increased deployment is modest" based on environmental considerations relates a biased conclusion. PV and wind farms also have broader environmental contraints which are not mentioned. I suggest "but the potential for increased deployment is limited by geographical context and should balance broader environmental contraints".	Noted: The paragraph has been substantially revised to limit discussion of the characteristics of specific options and simply to point out that many are available for near-term reductions.	Kurt Kornelsen	Ontario Power Generation	Canada
85325	5	28	5	28	the down side of hydrogen should also at this point highlight the localised storage and greater accessibility of pumped hydro	Noted: The paragraph has been substantially revised to limit discussion of the characteristics of specific options and simply to point out that many are available for near-term reductions.	Linda Hancock	Deakin University	Australia
745	5	29		37	Thoroughly check this paragraph	Taken into account. The message has been substantially revised and simplified to focus model ciretly on the points that (1) there are some good options, particularly in electricity and light-duty transport, but (2) these will not be enough.	Alok Dhaundiyal	Szent Istvan University	Hungary
1755	5	29	5	38	Solar PV and wind can displace most fossil fuel services at low cost (Bin Lu, Andrew Blakers, Matthew Stocks, Cheng Cheng, Anna Nadolny, "A zero-carbon, reliable and affordable energy future in Australia", Energy, Volume 220, 2021, https://doi.org/10.1016/j.energy.2020.119678). Its neither difficult nor expensive to remove most fossil fuels fro mthe economy.	Noted The message has been substantially revised and simplified to focus model ciretly on the points that (1) there are some good options, particularly in electricity and light-duty transport, but (2) these will not be enough.	Andrew Blakers	Australian National University	Australia
12189	5	29	5	38	We believe that the "development of new nuclear build and nuclear innovative projects such as Generation IV reactors and SMRs" should be added to the list of actions to be taken to reduce smissions. In its Energy, Electricity and Nuclear Power Estimates for the Period up to 2050, the International Atomic Energy Agency's (IAEA) high case projection has global nuclear generating capacity increasing from 392 GWe in 2017 to 511 GWe by 2030, 641 by 2040 and 748 by 2050. In the European Union, nuclear power avoided the emission of more that 20 Gt CO2 over the past 50 years which would have been otherwise produced if the same amount of electricity was produced using conventional fuel. Nuclear power can have a reverse effect on global warming, as energy need is projected to increase.	Noted The message has been substantially revised and simplified to focus model ciretly on the points that (1) there are some good options, particularly in electricity and light-duty transport, but (2) these will not be enough.	Lavinia Rizea	SN Nuclearelectrica SA	Romania
28359	5	29	5	38	The following energy sector mitigation options should be added as providing more immediate emissions reductions than others: (i) Nuclear CHP (cogeneration of electricity and heat for district heating or desalination, a quite mature technology [1]) and corresponding backfitting of existing plants; (ii) Small modular reactors for electricity production and district heating. In line 33 "electric heaters ("heat pumps")" should be replaced by "electric heaters and heat pumps" because of their different meaning. [1] Opportunities for Cogeneration with Nuclear Energy, IAEA Nuclear Energy Series No. NP-T-4.1 (2017)	Noted The message has been substantially revised and simplified to focus model ciretly on the points that (1) there are some good options, particularly in electricity and light-duty transport, but (2) these will not be enough.	Sevostian Bechta	KTH-Royal Institute of Technology	Sweden
42967	5	29	5	37	This section highlights replacing gasoline cars with electric vehicles. I agree with the point, but there should be the recognition that this also requires the creation of new generation capacity, not just replacing existing infrastructure. I think electrified mass transit should also be highlighted as a viable option.	Noted The message has been substantially revised and simplified to focus model ciretly on the points that (1) there are some good options, particularly in electricity and light-duty transport, but (2) these will not be enough.	Kurt Kornelsen	Ontario Power Generation	Canada

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
82293	5	29	5	38	You have in your chapter almost ignored district heating and district cooling. See further comments on Chapter 6 page 87. To replace district heating with heat-pumps in homes would increase the peak demand during winter time (especially during cold hours when the wind might now blow as much), hence increase the demand for peak hour power capacity, hence make it more difficult to reach net-zero emissions. (See also my comment on Chapter 6 page 87). In the Executive Summery, change FROM "…installing electric heaters ("heat pumps") in homes and businesses;" TO "…installing electric heaters ("heat pumps") in homes, businesses and district heating networks;"	Noted The message has been substantially revised and simplified to focus model ciretly on the points that (1) there are some good options, particularly in electricity and light-duty transport, but (2) these will not be enough.	Anna Krook-Riekkola	Luleå University of Technology	Sweden
74871	5	31	5	32	Plants that have already been committed and with signed contracts cannot be discarded without heavy consequences. Perhaps the way forward is to lobby for smaller units and minimize dispatch in the grid network (can be used as peaking units alone and provision of reserve capacity)	Noted The message has been substantially revised and simplified to focus model ciretly on the points that (1) there are some good options, particularly in electricity and light-duty transport, but (2) these will not be enough.	Government of Kenya	Kenya Meteorological Service	Kenya
86607	5	31		33	The UK CCC ^th Carbon Budget Report even foresaw that gas may be phased out by 2035. see www.theccc.org.uk/wp-content/uploads/2020/12/Sector-summary-Electricity-generation.pdf p.5. A similar point is made on page 6 of this chapter at line 4.	Noted The message has been substantially revised and simplified to focus model ciretly on the points that (1) there are some good options, particularly in electricity and light-duty transport, but (2) these will not be enough.	Mark Hinnells	Ricardo Energy and Environment	United Kingdom (of Great Britain and Northern Ireland)
55587	5	32	5	33	Should this not be assuring any gas-fired plants are compatible with net zero fuels such as H2, RNG, blends?	Noted The message has been substantially revised and simplified to focus model ciretly on the points that (1) there are some good options, particularly in electricity and light-duty transport, but (2) these will not be enough.	Government of United States of America	U.S. Department of State	United States of America
18207	5	33	5	33	installing electric heaters ("heat pumps")'. Not all electric heaters are heat pumps - better worded as 'installing electric heat pumps'	Noted The message has been substantially revised and simplified to focus model ciretly on the points that (1) there are some good options, particularly in electricity and light-duty transport, but (2) these will not be enough.	Government of United Kingdom (of Great Britain and Northern Ireland)	Department for Business, Energy & Industrial Strategy	United Kingdom (of Great Britain and Northern Ireland)
20877	5	33	5	34	This sentence is a shortcut that can lead to confusion and misinterpretation: on the one hand, the replacement of internal combustion vehicles by electric vehicles only makes sense if, at the same time and in the same proportions, the electricity consumed is decarbonized; on the other hand, life cycle analysis leads to a model where the number of vehicles on the road must be reduced. The 1:1 replacement of a thermal vehicle by an electric vehicle is not the sustainable model. In this respect, figure 6.1 shows a decline in the final energy consumption of the transport sector in 2065.	Noted The message has been substantially revised and simplified to focus model ciretly on the points that (1) there are some good options, particularly in electricity and light-duty transport, but (2) these will not be enough.	Government of France	Ministère de la Transition écologique et solidaire	France
20879	5	33	5	34	Could be added : better insulate poorly insulated houses	Noted The message has been substantially revised and simplified to focus model ciretly on the points that (1) there are some good options, particularly in electricity and light-duty transport, but (2) these will not be enough.	Government of France	Ministère de la Transition écologique et solidaire	France
30703	5	33	5	34	Installing electric heaters and replacing cars using gasoline with those using electricity are not always efficient measures for emission reduction, considering the emission intensity of electricity in near term. It would be better to state that it is important to keep pace with the measures to reduce the emission intensity of electricity as mentioned above.	Noted The message has been substantially revised and simplified to focus model ciretly on the points that (1) there are some good options, particularly in electricity and light-duty transport, but (2) these will not be enough.	Government of Japan	Climate Change Division - Ministry of Foreign Affairs	Japan

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
51337	5	33			installing electric heaters (“heat pumps”) and improving insulation in homes and businesses	Noted The message has been substantially revised and simplified to focus model ciretly on the points that (1) there are some good options, particularly in electricity and light-duty transport, but (2) these will not be enough.	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
63117	5	34			Need to add language such as "from non-fossil energy sources" after "electricity"	Noted The message has been substantially revised and simplified to focus model ciretly on the points that (1) there are some good options, particularly in electricity and light-duty transport, but (2) these will not be enough.	Jennifer Sklarew	George Mason University	United States of America
76575	5	34	5	34	cars using gasoline should be replaced with those using electricity and hydrogen.	Noted The message has been substantially revised and simplified to focus model ciretly on the points that (1) there are some good options, particularly in electricity and light-duty transport, but (2) these will not be enough.	Armin Winkler	University of Applied Sciences Upper Austria	Austria
30699	5	35	5	37	As a method for decarbonization, not only hydrogen extracted from the electrolysis of water, but also the combination of hydrogen extracted in the processo of fossil fuel with CCS is important..	Noted The message has been substantially revised and simplified to focus model ciretly on the points that (1) there are some good options, particularly in electricity and light-duty transport, but (2) these will not be enough.	Government of Japan	Climate Change Division - Ministry of Foreign Affairs	Japan
52141	5	35	5	38	Nuclear power is not mentioned as an option.Should be included	Noted The message has been substantially revised and simplified to focus model ciretly on the points that (1) there are some good options, particularly in electricity and light-duty transport, but (2) these will not be enough.	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
55589	5	35	5	35	Recommend restructuring this paragraph. Suggested rewrite: "These should be accompanied by efforts to advance technologies that will be important to decarbonize other sectors, such as off-road and heavy-duty transportation, long duration energy storage, industrial heating and chemicals manufacturing, and power generation."	Noted The message has been substantially revised and simplified to focus model ciretly on the points that (1) there are some good options, particularly in electricity and light-duty transport, but (2) these will not be enough.	Government of United States of America	U.S. Department of State	United States of America
29553	5	39	5	45	In addition, many countries are endowed with fossil fuels as a domestic resource - with new discoveries being made, which means the trade-off between clean energy supply and other societal objectives become even more pronounced. Please consider also including this perspective in the executive summary	Rejected: Space constraints limit the detail of messages in the ES.	Government of Norway	Norwegian Environment Agency	Norway
73939	5	39	5	40	suggestion to simplify the first statement: "The energy transition speed and scope will be subjected to broader societal objectives and public acceptance."	Noted: Sentence has been revised	Heleno Miguel	Lawrence Berkeley National Laboratory	United States of America
82085	5	39	5	45	The paragraph is very relevant inmentioning the importance of taking into account societal objectives. I just think that here it is also important to mention that these societal objectives can vary between regions. This could also be linked to the fact that becuase these changes should not hinder development, greater responsibility is placed on developed countries (as per the Paris Climate Agreement).	Taken into Account. This is mentioned in the message.	Sofia Rosero Abad	University	Netherlands
63119	5	42			Need to add water security and health	Accepted	Jennifer Sklarew	George Mason University	United States of America
80121	5	42	5	42	Energy systems are linked to air and water pollution , safety of the energy and food	Taken into account. These are included in the list	Emil Kichev	Technical University of Sofia	Bulgaria

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
52143	5	44	5	45	"Energy system transformation will not occur if it strongly conflicts with these goals." Sentence is too dispositive; should be qualified.	Taken into account. This sentence has been removed.	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
747	5	46		48	Rewrite	Accepted	Alok Dhaundiyal	Szent Istvan University	Hungary
55591	5	46	6	8	In addition to stranded fossil generation and refining assets, have the authors also considered oil and gas production assets in this recommendation? If so, indicate such. If not, indicate in the statement and elsewhere why investments in oil and gas production will not become stranded assets.	Taken into Account. Message has been simplified.	Government of United States of America	U.S. Department of State	United States of America
61555	5	46	6	8	need to address the role of fossil fuel energy/power with CCUS, including ga, LNG and blue hydrogen, as transition fuels and impact on stranded assets arguement.	Taken into Account. Message has been simplified.	tom howes	International Energy Agency	France
63121	5	46			The term "energy system mitigation" may be unclear to some readers. Suggest clarifying/defining as "carbon mitigation in energy systems" here.	Taken into Account. Message has been simplified.	Jennifer Sklarew	George Mason University	United States of America
49753	6	1	6	1	'Fossil Generation', 'Coal Generation' may be replaced by 'Fossil fuel production' and 'coal production', respectively	Taken into Account. Message has been simplified.	PINAKI SARKAR	CSIR-CIMFR, Dhanbad	India
71519	6	2	6	4	When assessing GHG emissions of natural gas compared to coal it is important to take into consideration fugitive emissions (as mentioned on page 12 of the Chapter). Depending on assumptions on these emissions, gas might not even be better in the short term.	Taken into Account. Message has been simplified.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
74863	6	2	6	4	Natural gas (LNG) provides a good alternative for peaking capacity compared to coal. It offers a long term solution that has fast response capabilties in the grid network especially during emergency situtions compared to Pumped Hydro storage	Taken into Account. Message has been simplified.	Government of Kenya	Kenya Meteorological Service	Kenya
55593	6	3	6	4	Natural gas infrastructure may not need to be retired if used for H2, RNG vs. retirement.	Taken into Account. Message has been simplified.	Government of United States of America	U.S. Department of State	United States of America
2627	6	9	6	10	How is this system net-zero? It certainly includes GHG sources but I can't spot any GHG sinks. How are the remaining coal, natural gas and oil emissions compensated?	Noted: This comment seems to be directed at another part of the chpater	Jan Wohland	ETH Zurich	Switzerland
7845	6	9	6	9	patters should be patterns	Accepted	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
8881	6	9	6	16	Note Bloomberg New Finance recent creation and tracking of "energy transition" investment market: https://about.bnef.com/energy-transition-investment/	Noted. Thanks	Seth Dunn	ServiceMax	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
12191	6	9	6	16	With regards to investment, we believe that the IPCC report should clearly state that a level playing field for assessing the contribution of each low carbon energy source to achieving the 2050 zero emissions target should be implemented and that regulation should not be imposed in such a manner as to limit or gravely impair any energy source. We are referring here to the EU Taxonomy and the Delegated Acts which currently have excluded nuclear power from the possibility to access sustainable financing sources until the completion of a life cycle assessment of nuclear, analysis which was not required for any other energy source currently included in the taxonomy. The absence of a level playing field and equal assessment criteria of each energy source will impact the willingness of investors to fund certain low carbon energy projects, thus leading to grid imbalances and an increased cost of the transition	Accepted	Lavinia Rizea	SN Nuclearelectrica SA	Romania
17475	6	9	6	9	"patterns"	Accepted	Alaa Al Khourdajie	IPCC	United Kingdom (of Great Britain and Northern Ireland)
48725	6	9	6	9	Typo - “a shift in investment patters” change to “a shift in investment patterns”.	Accepted	Qi An	Energy Research Institute, National Development and Reform Commission of China	China
55595	6	9	6	9	"patterns" is misspelled	Accepted	Government of United States of America	U.S. Department of State	United States of America
60127	6	9	6	10	word patters to be repalced by patterns	Accepted	Umasankari Kannan	Bhabha Atomic Research Centre	India
63123	6	9			Spelling of "patterns" needs to be corrected	Accepted	Jennifer Sklarew	George Mason University	United States of America
74081	6	9	6	9	change "patters" to "patterns"	Accepted	Beate Antonich	Center for Climate Change, Energy and Environmental Law (CCEEL) School of Law, University of Eastern Finland	United States of America
74181	6	9	6	16	Advanced nuclear should also be referenced in this section. https://www.sciencemag.org/news/2020/10/department-energy-picks-two-advanced-nuclear-reactors-demonstration-projects	Rejected: renewable energy and non-fossil transportation are examples only.	Jeffrey Merrifield	Pillsbury Law Firm	United States of America
28361	6	10	6	11	The replacement of “ ... such as renewable energy industries or non-fossil transportation are set ... “ by “... such as low carbon energy industries and transport are set...” is needed to have this statement of high confidence.	Taken into account. We have now used the word "very likely" to communicate a level of confidence. We are confident that these industries are likely to increase substantially.	Sevostian Bechta	KTH-Royal Institute of Technology	Sweden
55597	6	10	6	11	Renewable energy industries are not "emerging".	Accepted	Government of United States of America	U.S. Department of State	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
63125	6	11			Need a comma between "transportation are"	Accepted	Jennifer Sklarew	George Mason University	United States of America
749	6	12		14	Rewrite	Taken into Account. The statement has been revised.	Alok Dhaundiyal	Szent Istvan University	Hungary
55599	6	12	6	12	Change to "rapid expansion of investment in low carbon energy supply"	Accepted	Government of United States of America	U.S. Department of State	United States of America
1697	6	13	6	16	current investment is USD 1.8 trillion per year. If warming is limited to 2°C, the lower investment in 2030 is only USD 1.5 trillion, which is lower than the current level. Do you mean it is possible to have a decreasing investments until 2030? Then this is not "gradually increase".	Taken into Account. The statement has been revised.	Taoyuan Wei	CICERO Center for International Climate Research	Norway
751	6	17		25	Selection of words is not appropriate.	Noted	Alok Dhaundiyal	Szent Istvan University	Hungary
15825	6	17	6	19	"Near-term costs are heavily dependent on the costs of reducing emissions from electricity and increasing electrification, and they may well be negative or zero in some circumstances." It is true that decarbonizing electricity and increasing electrification are first placed in the merit order of all available decarbonizing strategies. But to say that their cost is negative usually raises skepticism among economists: if costs are negative,why are they not adopted massively and spontaneously? This debate is often forgotten when the famous McKinsey abatement curves are mentioned with no comment.	Rejected. There are multiple circumstances in which low-carbon options are cheaper than emissions intensive options.	Jean-Michel Trochet	EDF group (French Utility)	France
30705	6	19	6	19	There is no sentence in the report explaining that "They may well be nagative or zero in some circumstances". Therefore the line should be deleted.	Taken into account. The language has been revised, and the linkage is not in the report.	Government of Japan	Climate Change Division - Ministry of Foreign Affairs	Japan
52145	6	19	6	19	Phrase regarding negative or zero costs for emission reductions is not supported and unlikely particularly in any meaningful amount.	Rejected. There are multiple circumstances in which low-carbon options are cheaper than emissions intensive options.	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
64589	6	19	6	19	See previous comment: "negative or net zero (costs)" present an unwarranted optimistic view.	Rejected. There are multiple circumstances in which low-carbon options are cheaper than emissions intensive options.	Government of Netherlands	Ministry of Economic Affairs and Climate Policy	Netherlands
5321	6	21	6	21	Add after interest rates : "massive financial support by governrments". This has to be mentioned, because these policies are the major factor boosting Wind and solar, too expensive at the early stages for private investment.	Rejected. We do not have space to make all points in the ES. We do mention investments in another message.	Michel SIMON	Retraité/ Pdt d'association	France
17317	6	22	6	22	transport is often mentioned in Chapter 6. Who takes care that the contents does not overlap with a special chapter dedicated only to the transport?	Noted. There are processes to try to adress overlap, but not all of it can be eliminated.	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
5323	6	23	6	23	Add after 75% : However, the contribution of wind and solar remain modest, under a mere 4% of electricity production. (See Chpter 6,3,5)	Noted. I think this is misplaced. Don't worry about it.	Michel SIMON	Retraité/ Pdt d'association	France
37657	6	24	6	24	The text here refers to "second-generation biofuels and hydrogen". It may please be expanded to include next generation nuclear reactors.	Rejected. This is an illustrative list, and we have not included all options that would alter the economics of mitigation	Ravi B Grover	Homi Bhabha National Institute	India

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
77989	6	24	6	24	In this statement, CO2-based fuels/e-fuels and chemicals should be added together with biofuels and hydrogen even though IAM's failed in considering e-fuels and chemicals (as discussed in Annex C). Still other research uses a broad set of e-fuels and chemcials, which comprise e-methane, e-methanol, Fischer-Tropsch fuels. TThe role of these e-fuels is discussed into much details in the following study. (https://www.powerfuels.org/fileadmin/powerfuels.org/Dokumente/Global_Alliance_Powerfuels_Study_Powerfuels_in_a_Renewable_Energy_World.pdf) of the German Energy Agency and the scientifc description is documented in Bogdanov et al. (https://www.sciencedirect.com/science/article/pii/S0306261920316639).	Rejected. This is an illustrative list, and we have not included all options that would alter the economics of mitigation	Célia Sapart	Université Libre de Bruxelles / CO2 Value Europe	Belgium
78581	6	24	6	24	synthetic fuels and chemicals' shall be added to 'biofuels and hydrogen'. It is well known (and documented in Annex C) that IAMs are blind for synthetic fuels and chemicals beyond hydrogen, as it's simply not part of the methods in the major IAMs. Still other research uses a broad set of synthetic fuels and chemcials, which comprise synthetic methane, Fischer-Tropsch fuels, synthetic (green) ammonia and methanol. The relevance has been shown in this report (https://www.powerfuels.org/fileadmin/powerfuels.org/Dokumente/Global_Alliance_Powerfuels_Study_Powerfuels_in_a_Renewable_Energy_World.pdf) of the German Energy Agency and the scientifc description is documented in Bogdanov et al. (https://www.sciencedirect.com/science/article/pii/S0306261920316639).	Rejected. This is an illustrative list, and we have not included all options that would alter the economics of mitigation	Christian Breyer	LUT University	Finland
51469	6	25			of net-zero energy systems (Medium confidence) {6.4, 6.7}, and the decreasing cost of green hydrogen is making it	Noted. We do not understand the comment	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
51471	6	25			an increasingly attractive clean fuel.	Noted. We do not understand the comment	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
85327	6	25	6	25	along with hydrogen ammonia as a more transportable fuel with potential applications to petrol substitution should be mentioned here now that two way conversions between ammonia and hydrogen for transportation are possible [see Australian reseatch by CSIRO and Monash University]	Rjected. This is too detailed for the ES	Linda Hancock	Deakin University	Australia
17315	6	46	6	46	"...stranded assets…" Fossile fuel reserves and infractructure may become stranded assets, if the whole World works together on decarbonization. But so far, even the most developed countries (Norway-gas,oil, USA-gas,oil, Australia - coal) or China with its new coal plants do not seem to be too concerned about that. They continue to generate a huge amount of their GDP from these resources. All other energy infrastructure may become stranded assests (nuclear, other renewables). So this is a rather speculative paragraph.	Rejected. The point is that if warming is limited, then we will see stranded assets.	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
17175	7	1	7	1	The projection for 2065 (net-zero CO2 emission) for nuclear power is not right, it is inconsistent with documents from IPCC and IEA (cited as sources for this figure 6.1), and not consistent with the nuclear production figures/ranges Chapter 3, page 41 Figure 3.16. Indeed, the references for this table 6.1 are EIA and IPCC, but in recent reports (2018: SR15 https://www.ipcc.ch/sr15/), an increase in nuclear power production is expected + the same in figure 3.16 the 2050 and 2100 projections predict an increase in nuclear power, while figure 6.1 shows a virtual stop of nuclear power in 2065 (a level divided by 20 compared to 2018).	Rejected: IEA source is 2018 only. For 2065 this is based on deep electrification scenario. Figures are correct but will be checked. For final version 2045 date is retained as it matches the year when net zero emissions will be reached.	Government of Poland	Ministry of Environment, Department of Air Protection and Climate	Poland
18213	7	1	7	1	Nuclear output in Sankey diagram is very small (all the others the flow size = node size). There may be an error here, or are all power conversion losses being taken by nuclear? Fig6.1	Rejected: IEA source is 2018 only. For 2065 this is based on deep electrification scenario. Figures are correct but will be checked. For final version 2045 date is retained as it matches the year when net zero emissions will be reached.	Government of United Kingdom (of Great Britain and Northern Ireland)	Department for Business, Energy & Industrial Strategy	United Kingdom (of Great Britain and Northern Ireland)
28447	7	1	127	28	The structure of the report is often confusing. I feel this is a missed opportunity as there is a clear storyline to be told which will result in a better readable and more effective text. Most logical to me would be start with the current system and trends, than focus on how the end goals of net-zero could be obtained. Than parthways towards that goal leading to actions that could be done today. Only after this focus on more detailed subchapters like the effects of climate change and the effects it has on the transition pathways outlined before. This way the document could become a clear vision on what concrete steps in the near future are and how they could eventually lead to potential pathways towards a net-zero economy. Also sections like 6.7.1 are quite similar to sections on net-zero, and specific sections like 6.7.5 and 6.7.6 have their own chapters within the entire IPCC report, but these are not clearly refered to in these sections. I understand this is hard to adress in a review but certainly the structure of the summary or lay-out of the chapter of such an influential document as this is going to be is worth to have another look at.	Rejected. We believe the current format works well with the task that we were given. We do, in fact follow the structure you suggest. We discuss current trends first, then we discuss mitigation options and how climate might effect then, then we talk about the net-zero world, and then we discuss pathwas to get there.	Naud Loomans	Eindhoven University of Technology	Netherlands
64147	7	1	127	28	The entire chapter needs proof reading. Some examples are: (i) page 8 row 45 & 46, Many people are employed in the energy sector, and energy system mitigation will reduce eliminate some jobs while creating others. (ii) page 10, Figure 6.2, No units on both y-axis i.e., million tonnes per year. Similary there are no units on three graphs of Figure 6.3. (iii) page 51, row 15. They can start more quickly, operate.... (iv) page 77 row 46 to page 78 row 3. The text is repetition(see page 77 rows 40-46) and should be deleted.	Accepted	Ghulam Rasul Athar	Pakistan Atomic Energy Commission	Pakistan

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
64409	7	1	127	28	There is mention of the time required to plan, permit, and construct a new hydroelectric power plant, which I think is a core topic that is not adequately addressed throughout this chapter for all technologies in an integrated manner. I would like to see a figure illustrating the typical time required to implement each form of mitigation (wind, solar, battery storage, pumped hydro, hydro, nuclear, electric transmission). I would also like to see a figure that integrates this timeline for each technology into the rate of energy transition required to meet 1.5 and 2C pathways. Solar facilities and battery storage are developed very quickly, onshore wind slightly slower, offshore wind slower still, and hydro and nuclear are positively glacial in the development/permitting/engineering/construction timeline. All technologies require grid improvements, including long-distance high-voltage electric transmission lines. These lines also have a long timeline from initial planning until operations (often greater than ten years). As a general comment, I don't think this chapter does a sufficient job of identifying that the discrepancy in time to implement the various technologies is one of the greatest impediments to meet GHG mitigation goals. Grid improvements and pumped hydro take too long to facilitate rapid and widespread implementation of deep penetration of renewable energy. One only needs to look at interconnection queue requests to get confirmation that there is a backlog of projects. This issue is at the heart of the challenge before us and should be a central thesis of the chapter.	Rejected. This is an interesting idea, but we will not be able to take it on due to space constraints.	Curt Bjurlin	Stantec Consulting	United States of America
64427	7	1	127	28	As a general question, how much time is devoted for primary authors of individual sections to review and comment on other sections within this chapter? There is a wide range in the detail provided for specific mitigation options, the treatment of the challenges associated with the options, and the extent to which supporting literature is cited. If not currently being implemented, suggest that each primary author be assigned several other sections to read and comment on to increase overall consistency in the style and approach of the analysis.	Taken into Account. We have worked to get more cross-chapter engagement.	Curt Bjurlin	Stantec Consulting	United States of America
79513	7	1			A box "Energy primer and climate change" could be useful to recall the difference form of energy, the difference between ressource and energy carrier, the thermal loss in thermal transformation (entropy), the energy density of the various fuels, the emission factors, and some of the abrevaition such as DAC(not listed in the annex) CDR, CCS,, CCUS. This could allow reading by further non-specialist.In earlier AR this has been done as introduction to the energy section more or less (AR4).	Rejected. This is an interesting idea, but we will not be able to take it on due to space constraints.	Marc Daras	CentraleSupelecAlumni	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
82297	7	2	7	7	A comment: From a comprehensive energy system perspective (and also what we need when discussing sector coupling), the energy system goes beyond what is illustrated in figure 6.1. The figures “ends” at Final consumption, while the energy system in traditional comprehensive energy system modeling approach “ends” at that we have a demand for energy intensive service and goods. See e.g. Figure 1.1 in GEA, 2012: Global Energy Assessment - Toward a Sustainable Future, Cambridge University Press, Cambridge, UK and New York, NY, USA and the International Institute for Applied Systems Analysis, Laxenburg, Austria. Which can be downloaded from here: https://iiasa.ac.at/web/home/research/Flagship-Projects/Global-Energy-Assessment/Home-GEA.en.html I suggest to replace Figure 6.1. with one in line with Figure 1.1. by GEA (2012), or at least add the GEA figure. OR, if you mean something else with energy system from what I have described above (and what is common when discussing sector coupling), describe that there are different ways on interpreting ‘energy system’ – describe the different ways and motivate why you have chosen your approach.	Rejected. The purpose of the diagram is to to show at scale the evolution of the real energy system. Beyond the final energy, there are no global database. Section 6.2 provides comprehensive development on energy systems beyond the physical energy systems. It must be also highlighted that IEA and other countries have similar diagrams with a representation of all the flows.	Anna Krook-Riekkola	Luleå University of Technology	Sweden
753	7	3			Explain this limiting warming ? Global, earth, ocean, climate…..	Noted. Obvious	Alok Dhaundiyal	Szent Istvan University	Hungary
755	7	3		4	different from	Accepted	Alok Dhaundiyal	Szent Istvan University	Hungary
43837	7	3	7	4	The sentence in this portion must also cover the goals, not just of the Paris Agreement, but also other international commitments such as the UN SDGs or the Agenda 2030 and other protocols. The goal of energy transition is not just to engage countries to pursue ambitious avoidance and reduction pledges but also to encourage them to exert their very best to provide their people the basic access to affordable, reliable, and sustainable energy. I prefer the phrasing such as: Future energy systems will differ from the current systems if the world will succeed in achieving a sustainable energy landscape."	Rejected. The focus in this sentence is on the implications of limiting warming.	Vince Davidson Pacañot	University of the Philippines Diliman	Philippines
64115	7	3	7	3	The word 'Global' is needed before warming because it is used for the first time in this chapter,	Rejected. Obvious	Ghulam Rasul Athar	Pakistan Atomic Energy Commission	Pakistan
74761	7	3	7	4	Limiting warming to 1.5 oC is already below 2 oC. Hence, the sentence "The energy systems of the future will be very different 4 than those of today if the world is successful in limiting warming to well below 2°C or to 1.5 C" may be considered for revision.	Accepted	Semilore Abikoye	Department of Chemical Engineering, University of Cape Town	South Africa
74763	7	3	7	3	Kindly note that the correct term should be "1.5 °C" and not "1.5 C".	Accepted	Semilore Abikoye	Department of Chemical Engineering, University of Cape Town	South Africa
757	7	4			remove 'to' is it range of temperature or different value ?	Taken into account. Sentence has been revised.	Alok Dhaundiyal	Szent Istvan University	Hungary

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
7847	7	4	7	4	1.5 C should be 1.5°C	Accepted	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
61953	7	4	7	4	Typo: change "1.5 C" to "1.5°C".	Accepted	Esa Vakkilainen	LUT University, Lappeenranta	Finland
64591	7	4	7	5	Stress that Figure 6.1 is just one example of the future energy system, not "the" or "the best" or "most likely". Change "(Figure 6.1)" to "(see Figure 6.1 for one example)" or something similar.	Accepted. This will be explicitly mentioned	Government of Netherlands	Ministry of Economic Affairs and Climate Policy	Netherlands
759	7	8			legend is missing (6.1). Figures are unclear	Rejected. No need for the legend here. Comments for others show that the diagram is rather understandable.	Alok Dhaundiyal	Szent Istvan University	Hungary
5325	7	8	7	16	The wording of ths alinea is rathr strange. Author starts by stating : "Electricity systems powered predominantly by renewables will be increasingly viable" , an assertion which is not validated as beyons 40% of intermittent source, the network is at risk. And conclude some lines below, that the ability to overcome the economic, regulatory and operational challenges is not granted. As of today, no one has the solution, and thus you cannot claim that solar and wind wil be the predominant sources.	Rejected. We believe this to be true and discuss it extensively in the chapter	Michel SIMON	Retraité/ Pdt d'association	France
18215	7	8	7	9	Both these important figures have a lot going on in them and as a result users could very easily just skip over these. I think they may need to either be simplified or made 'nicer' to look at to draw in readers.	Accepted. The look of these figures will be improved during the production process.	Government of United Kingdom (of Great Britain and Northern Ireland)	Department for Business, Energy & Industrial Strategy	United Kingdom (of Great Britain and Northern Ireland)
55601	7	8	7	9	Figure 6.1 shows power plants in the middle in red (not labeled, but identified in the second figure), but the amount of energy lost due to waste is not quantified.	partially accepted . The main purpose is a visual illustration of the flows. Not all flows are quantified. This is the case for waste. In revised diagram wastes from power generation are limited to transport and distribution losses.	Government of United States of America	U.S. Department of State	United States of America
79507	7	8			Fif 6.1 Energy system 2065.The proposed primary energy, 579EJ, is similar to present TPES, 588 EJ, as Final consumption. This pose 2 questions: 1. Should Ipcc propose a target volume for energy and at which level; 2. In terme of consistency, p91, l 26-38, the lead author et al. propose a range of value for total fianl energy consumption from a review of scenarii between 210 EJ and 1080 EJ from my calculation, and a median value of 555EJ. Similarly, Irena, Global renewable Outlook 2050, give a range 400-800 EJ for TPES from its analysis of various published scenarii fig 1.17, p90 which give a lower value for upper limit of TFE. I understand that the purpose is to illustrate the change in the energy system organisation, but to show only one scenario (without reference) is problematic. However I have no solution here.	Accepted. We shall highlight that it is only one scenario and why this scenario. We can't have all scenarios in this diagram.	Marc Daras	CentraleSupelecAlumni	France
79509	7	8			In the present stage of the figure, the loss on the figureis very small, while it represents 200EJ appr.	Noted Figures for losses revised. For 2045 losses are illustrative.	Marc Daras	CentraleSupelecAlumni	France
80145	7	8	7	10	The text on this figure could potentially be enlarged somewhat to be easier to read; overall, I thought the graphics throughout this chapter were well done, and I commend the authors for their dedicated work!	Accepted. We shall either keep the figures and enlarge or delete and only illustrative.	Robin Happel	Yale Center for Environmental Law & Policy	United States of America
85467	7	8	7	10	I really hope you keep these two figures and maybe explain them a little bit. To many readers this will provide just as information as the rest of the chapter I'm afraid.	Noted Keep the diagram.	Auke Hoekstra	Eindhoven University of Technology	Netherlands

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
86609	7	8	8	5	The Sankey Diagrammes are very useful, and do say they are subject to revision, but Im not sure they show aviation and shipping yet in terms of both biomass and waste derived or hydrogen derived fuel, particularly if aviation does increase as expected globally	Noted. It will be specified that figures are based on one scenario and why this scenario.	Mark Hinnells	Ricardo Energy and Environment	United Kingdom (of Great Britain and Northern Ireland)
5329	7	9	7	10	Fig 6.1, second figure.forecast in 2065. How the data has been established? Giving that projection, you imply it is the most likely projection. Do you really believe it? The data for solar is just un reasonable. The data for nuclear is obviuously false, unless you assume that the plants under construction or schedumed will be shutdown? This figure is just a fantasy.	Accepted in 2045 biomass as direct use will be added.	Michel SIMON	Retraité/ Pdt d'association	France
64117	7	9	7	10	Electricity is the only fuel in energy supply system of residential/commercial sectors in 2065. Direct use of Bio-energy and soft solar may also be considered.	Rejected. Purpose of the diagrams is to show evolution of energy systems based on real figures. Losses are represented.	Ghulam Rasul Athar	Pakistan Atomic Energy Commission	Pakistan
84271	7	9	7	10	The bottom Sankey's figure is at concern: According to the 2nd principle of thermodynamics, the 2065 illustrative energy system is not: (i) globally operable, by a lack of inertia provided by moving mass in dammed hydro or thermal plants; or conversely (ii) by the under-estimation or the lack of extra-energy to spend for ancillary services, especially for a more agile IT-control; and (ii) a tension on structural and functional materials for an highly diluted energy system which provides additional and non-linear extra-energy consumption (for mining extraction or circularity). A more consensual vision should be found to fully convince of the effort to pay for the transition with several nexus rooted by the notion of entropy: "energy-information" nexus and "energy-material" nexus (beside the well-known "water-energy" nexus).	Noted.	Vincent MAZAURIC	Schneider Electric	France
15521	7	10	7	10	for the 2065 scenario is given as an illustration from the IPCC database. Instead, it is proposed to take pictures from Energy Technology Perspective 2020, IEA OECD, https://www. iea. org/reports/energy-technology-perspectives-2020/etp-model#abstract	Accepted. It will be specified why this date and why this scenario. It will be 2045. Net zero emissions	Vladimir Kucinov	National Research Nuclear University "MEPHI" (Moslow Enginiring Physical Institute)	Russian Federation
17319	7	10	7	10	What is the role of this figure for 2065? Why 2065? Is that a wish, official goal or just one of the scenarios? Feasibility studies are where?	Accepted. We shall specify why this scenario 2065. It will be replaced by 2045	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
42969	7	10	7	10	Is this figure related to a specific IEA scenario? If so the scenario should be identified. I am curious at the substantial drop in nuclear power in this figure.	Rejected. In the literature, this is not highlighted as a constraint. Furthermore solar roof does not require any land	Kurt Kornelsen	Ontario Power Generation	Canada
42975	7	10	7	10	The scenario in this figure seems implausible. To produce 189 EJ of solar energy with an energy density of PV at 6.63 W/m2 (https://doi.org/10.1016/j.enpol.2018.08.023) would require around 900 000 km^2. This is equivalent to covering the entire country of Pakistan in Solar PV!	Rejected Nuclear is indirectly related to hydrogen. The flow shows that electricity (part of which nuclear) is used to produce hydrogen.	Kurt Kornelsen	Ontario Power Generation	Canada

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
61749	7	10	8	5	Figure 6.1 displays a sketch of an energy system in 2065. There is no storage component to account for the variability of solar and wind. Nuclear should be connected to hydrogen production as, according to literature, it is likely the most viable option for large-scale clean hydrogen production. A paper cited in this report (Graves et al., 2011, https://doi.org/10.1016/j.rser.2010.07.014) concludes that "[t]he dominant costs of the process are the electricity cost and the capital cost of the electrolyzer, and this capital cost is significantly increased when operating intermittently (on renewable power sources such as solar and wind)". The paper (Kayfeci et at. 2019, https://doi.org/10.1016/B978-0-12-814853-2.00003-5) lists hydrogen from nuclear at a price by far cheaper than from solar or wind. Further, LucidCatalyst (2020, https://www.lucidcatalyst.com/hydrogen-report) lists hydrogen from existing nuclear PWR technology at less than $2/kg and from GEN IV technology at $1/kg or less.	Noted	Rauli Partanen	Think Atom	Finland
61955	7	10	7	10	Typo: in Energy System 2065: Change "conver-other gases" to "Convert-other gases"	Accepted	Esa Vakkilainen	LUT University, Lappeenranta	Finland
65781	7	10	8	5	Figure 6.1 displays a sketch of an energy system in 2065. Where is the necessary storage component to account for the variability of solar and wind? Why is nuclear not connected to hydrogen production although, according to literature, it is likely the most viable option for large-scale clean hydrogen production. A paper cited in this report (Graves et al., 2011, https://doi.org/10.1016/j.rser.2010.07.014) concludes that "[t]he dominant costs of the process are the electricity cost and the capital cost of the electrolyzer, and this capital cost is significantly increased when operating intermittently (on renewable power sources such as solar and wind)". COMMENT CONTINUES	Rejected. No need to show in the illustrative diagram storage. Nuclear is indirectly connected to hydrogen. Furthermore diagram will be an illustrative diagram.	Eero Hirvijoki	Aalto University	Finland
65783	7	10	8	5	COMMENT CONTINUES On page 44 of this report, hydrogen from biomass is estimated "(by 50-200%) cheaper than hydrogen produced from electrolysis utilising solar/wind resources". The paper (Kayfeci et at. 2019, https://doi.org/10.1016/B978-0-12-814853-2.00003-5) cited for this information lists hydrogen from nuclear at a price comparable to that from biomass and by far cheaper than from solar or wind. Furthermore, the report (LucidCatalyst, 2021, https://www.lucidcatalyst.com/hydrogen-report) lists hydrogen from existing nuclear PWR technology at less than $2/kg and from GENIV technology at $1/kg or less. Revise accordingly.	Noted. Consistency will be checked across chapters particularly for nuclear and chap 3 page 41 fig 316	Eero Hirvijoki	Aalto University	Finland
5327	7	18	7	19	The statement is false. Cost of electricity produced by wind or solar is higher than electricity produced by gas or nuclear. Lobbyists claim that renewable Mwh are cheaper when forgetting: the public subsidies, the fact that they benefit of priority acces to the grid. In addition, they compare a MWjh which is available when the consume needs it to a MWh available only when there is wind or sun. To be honest, it should be necessary to include the cost of storage or alternat source of supply, which lead to a cost substantially higher!! This sentence must be deleted or deeply modified. IPCC cannot reproduce wrong information.	Rejected: There is no line 18 on page 7	Michel SIMON	Retraité/ Pdt d'association	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
19651	7		7		The projection for 2065 (net-zero CO2 emission) for nuclear power is not correct, it is inconsistent with documents from IPCC and IEA (cited as sources for this figure 6.1), and not consistent with the nuclear production figures/ranges Chapter 3, page 41 Figure 3.16. The references for this table 6.1 are IEA and IPCC, but in recent reports (2018: SR15 https://www.ipcc.ch/sr15/), is expected an increase in nuclear power production.	Accepted. Direct biomass to buildings will be added. Note that only major flows are represented	Government of Slovakia	State Advisor, Climate Change Policy Department Ministry of the Environment	Slovakia
63621	7		7		On Figure 6.1, there is no direct use of biomass in industry or buildings, which is not accurate. Significant amounts of residues (hog fuel, black liquor) is used in forest industries and firewood in residential buildings. The size of Primary supply streams are not proportional to EJ supplied.	Noted. Share of nuclear.	Government of Canada	Environment and Climate Change Canada	Canada
77203	7				The possibility of using a sample net-zero emissions scenario representing a higher contribution from nuclear than what presented here should be considered, for this illustration to be more aligned to the current and long-term policies in a global context. Also, nuclear reactors (and high-temperature ones even more than present ones) are already, thus could also be in the future, used for direct production of heat (e.g., for industrial applications, production of hydrogen, heating), without the need for intermediate conversion to electricity.	Accepted. Hydrogen for transportation is included. Residential flows amended.	Giacomo Grasso	ENEA	Italy
20881	8	1	8	1	Figure 6.1 : - The graph in the bottom panel shows only industrial uses of hydrogen. However, hydrogen is considered to have significant applications for transportation. This should be reflected in the graph. - Is it to be understood from the bottom panel that the entire final energy consumption of the residential and commercial sectors expected in 2065 would be electric? Is this a forecast? A recommendation? What about the distribution of renewable heat and cold?	Noted. Agriculture is among other sectors.	Government of France	Ministère de la Transition écologique et solidaire	France
79511	8	5			energy for AFOLU and non energy applications (of??) should be counted in industry, or eventually a new final usage as agriculture, since it represents energy and not materail flow or GHG emissions	Rejected. This part of agriculture is limited to energy used by agriculture (based on IEA data) and not all emissions by agriculture.	Marc Daras	CentraleSupelecAlumni	France
761	8	6		15	Rewrite the whole paragraph in a proper manner. The sentences are not clear enough. Clearly state the objectives.	Taken into Account: the paragraph has been revised.	Alok Dhaundiyal	Szent Istvan University	Hungary
73941	8	6	8	7	It is not clear what "this second focus" is referring to.	Taken into Account: the paragraph has been revised.	Heleno Miguel	Lawrence Berkeley National Laboratory	United States of America
82299	8	6	8	10	Coming from a comprehensive energy system perspective, I am struggling with sentence 2 and 2 in this section. E.g. sentence three starts with “This second focus ….” (and then later start, the fourth sentence starts with “Second, ….”). Suggestion to rewrite sentence 2 and 3 as follow: First, it assesses specific, individual mitigation options in energy supply, transformation, and transportation/transmission and demand. The demand is only briefly described, when complementary to a set of chapters that explore mitigation options in each demand sector; agriculture, forestry, and other land uses (Chapter 7), urban systems and other settlements (Chapter 8), buildings (Chapter 9), transport 10 (Chapter 10), industry (Chapter 11), and cross-sectoral perspectives (Chapter 12).	Taken into Account: the paragraph has been revised.	Anna Krook-Riekkola	Luleå University of Technology	Sweden
1699	8	7	8	7	Should "This second focus" be "This focus"?	Taken into Account: the paragraph has been revised.	Taoyuan Wei	CICERO Center for International Climate Research	Norway

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
51339	8	7			energy supply, transformation, and transportation and transmission. This first focus is	Taken into Account: the paragraph has been revised.	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
74765	8	7	8	7	The use of 'and' before "tansportation" and "transmission" consecutively may have to be revised. A comma may also be introduced after the first 'and'	Taken into Account: the paragraph has been revised.	Semilore Abikoye	Department of Chemical Engineering, University of Cape Town	South Africa
74841	8	7	8	46	The sentense in Line 7 and 8 "This second focus is complementary to a set of chapters……" not clear. Line 38: governments can invest….Line 46: reduce or eliminate	Taken into Account: the paragraph has been revised.	Government of Kenya	Kenya Meteorological Service	Kenya
86519	8	7	8	7	"this second focus" should be "this primary focus"	Taken into Account: the paragraph has been revised.	raphael Slade	Imperial college	United Kingdom (of Great Britain and Northern Ireland)
74767	8	10	8	15	In my opinion, there is need for consistency and uniformity in refering to energy systems. While the entirety of energy systems is pluralised line 11 and line 12, and in line 14, the structure of the sentence starting on line 12 (ending on line 13), as well as the sentence starting on line 14 is not in agreement with the established stricture which considered the energy systems in plural terms	Taken into Account: the paragraph has been revised.	Semilore Abikoye	Department of Chemical Engineering, University of Cape Town	South Africa
72151	8	12	8	13	check repetition in "and end uses and end users"	Taken into Account: the paragraph has been revised.	Marta Victoria	Aarhus University	Denmark
43839	8	16	8	25	Please enumerate the questions that this chapter will address: either in numbered (1, 2,…) or bulleted form. To express these questions in a paragraph form would be taxing the readers. Let's make it easier to read or locate.	Taken into Account: the paragraph has been revised.	Vince Davidson Pacañot	University of the Philippines Diliman	Philippines
64177	8	16	8	25	Appears partial although the numbers appear OK. Providding universal acess is not a choice and would still be small given the historical consumption patterns and high level of inquality in present energy consumption globally. Might be a good idea to express a more nuanced view. There is a fair treatment of SD elsewhere in the chapter, might be good to bring some text here	Accepted. We now have a nod to the cross cutting issue of SDGs and othe societal priorities.	Minal Pathak	WGIII TSU, Ahmedabad University	India
80105	8	16	8	25	Within this context, this chapter 6 covers six questions, each of which is addressed in a separate section.	Taken into Account: the paragraph has been revised.	Emil Kichev	Technical University of Sofia	Bulgaria
80107	8	16	8	25	First: What is the scope of the energy systems and its possible evolution (Section 6.2)?	Taken into Account: the paragraph has been revised.	Emil Kichev	Technical University of Sofia	Bulgaria
80109	8	16	8	25	Second: Which recent trends in energy systems might exert the greatest influence on energy system evolution and options for reducing emissions (Section 6.3)?	Taken into Account: the paragraph has been revised.	Emil Kichev	Technical University of Sofia	Bulgaria
80111	8	16	8	25	Third: What is the status and potential of individual energy supply, transformation, storage, transportation and transmission, and integration options (Section 6.4)?	Taken into Account: the paragraph has been revised.	Emil Kichev	Technical University of Sofia	Bulgaria
80113	8	16	8	25	Fourth: How might climate change affect energy systems and alter potential energy system mitigation options and strategies (Section 6.5)?	Taken into Account: the paragraph has been revised.	Emil Kichev	Technical University of Sofia	Bulgaria
80115	8	16	8	25	Fifth: What are the key characteristics of “net-zero” energy systems – those that emit no CO2 or that actually sequester CO2 from the atmosphere (Section 6.6)?	Taken into Account: the paragraph has been revised.	Emil Kichev	Technical University of Sofia	Bulgaria

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
80117	8	16	8	25	Sixth: What are the transition pathways toward and through net-zero energy systems (Section 6.7)?	Taken into Account: the paragraph has been revised.	Emil Kichev	Technical University of Sofia	Bulgaria
84273	8	20	8	21	In the decription of §6.4, add "management" to include the stringent question of stability (of the system itself) and adequacy (between supply and demand-side). This is particularly critical fo the power system which (i) governs the operation of other commodities; and (ii) should take in any circumstance (<ms) its own conditions of operation from its power conversion process (for synchronism, inertia, control and monitoring...)	Rejected. This is a big topic for the chapter, but it doesn't need to be raised in the context of these general questions.	Vincent MAZAURIC	Schneider Electric	France
763	8	23			remove 'actually'. The paragraph is wordy.	Accepted	Alok Dhaundiyal	Szent Istvan University	Hungary
769	8	26	9	11	Scope of energy system in national development is missing, which is the key element. It merely focused on one type of energy source (solar). What about small-scale biomass power plant ? What about govt. subsidaries? Govt. does not invest directly but provide tax rebate (Feed-in tariff) to the companies, however it depends on the country policy. Bundling scheme, Viability gap funding for financially non viable projects, solar park... so on.. Must involve these schemes. Focus on EEG. Discuss tariff scale of the energy systems	Rejected. This is too detailed of a point to be raised at this point in the discussion..	Alok Dhaundiyal	Szent Istvan University	Hungary
52149	8	26	9	11	The chapter spends relatively little space on the broader energy system boundaries and issues; the chapter would be more focused if it dealt more with the physical energy system, its components and their interactions, than poorly addressing the social, political, and broader economic issues associated with energy systems.	Nioted. It is impossible to separate the physcial energy system from the social, political, and broader economic issues that surround it. We do, however, recognized that we cannot address these broader issues in detail, so we have focused most heavily on the physical energy system.	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
765	8	27			It is not necessary to write ' For the purpose of this chapter'. Avoid superfluous english.	Rejected. We disagree. This is how we define it for the purposes of this chapter. There may be other definitions.	Alok Dhaundiyal	Szent Istvan University	Hungary
767	8	27			The energy systems 'includes' or 'imbibes' both physical and ….'	Rejected. "Imbibes" is an odd word choice.	Alok Dhaundiyal	Szent Istvan University	Hungary
17187	8	27	9	11	This section does a good job of opening up the scope and complexity of energy systems. Perhaps it could also include some definitions preceding the next part, on emissions trends. The "power sector", "energy supply", "energy sector", and "fugitive emissions" are all discussed but could use a brief explanation. Figure 6.1 would be very useful for clarifying these.	Noted. There is already a definiton of the full system. Suggestion will be considered	William Lamb	Mercator Research Institute on Global Commons and Climate Change (MCC)	Germany
43841	8	31	8	46	(Part 1). Since we aim to introduce the scope and benefits that we can obtain from energy production through different energy systems, it is fair enough to likewise briefly state that energy systems do exhibit some negative externalities, especially in the aspect of human health due to air pollution. Some studies that can be cited are those by Grigg (2002) [1], Schwartz et al. (2019) [2], and Vohra et al. (2021) [3].	Noted. We cover negative externalities extensively in Section 6.4.	Vince Davidson Pacañot	University of the Philippines Diliman	Philippines
43843	8	31	8	46	(Part 2). Aside from these, government policies and their respective agencies are powerful drivers of energy development such that (1) they allow the incentivization of developing energy projects by different energy investors (both loca and foreign) thereby providing people their right to basic access to energy and (2) they empower communities through financial incentives directed towards the socio-economic development of the people, especially those that are part of host communities.	Noted. We cover policies at several places in the chapter, although there are other chapters that focus more directly on policy issues.	Vince Davidson Pacañot	University of the Philippines Diliman	Philippines
64119	8	31	8	32	1. 'to travel' is repetition. 2. 'to provide services' instead of 'to produce services'.	Accepted	Ghulam Rasul Athar	Pakistan Atomic Energy Commission	Pakistan

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
74769	8	31	8	32	One would assume "to transport themselves" as used in line 31 is the same as "to travel' as used in line 32. Is this not a repetition of function?	Accepted	Semilore Abikoye	Department of Chemical Engineering, University of Cape Town	South Africa
78241	8	33	8	36	Subjective - The reference suggests a change in usage pattern so as to put lesser load on demand appears unsubstantiated. This kind of argument requires a thorough study of dirunal requirements and feasiblity at large, meaningful sclaes.	Rejected. All that was stated was that end users control how and when they use energy. This seems pretty uncontroversial.	Reetesh Chaurasia	Department of Atomic Energy, Government of India	India
37659	8	34	8	34	Here a reference has been made to demand of energy at a particular time of the day. Any change imposed on the timing of demand will influence routine of women in the household. They could be subject to severe disadvantage. This kind of argument requires a deep think by social scientists.	Rejected. This is a simple statement that end users control how and when they use energy.	Ravi B Grover	Homi Bhabha National Institute	India
79515	8	36	8	39	The 2 sentences could read: "Consumer invest in local energy systems such as boilers, furnaces, rooftop solar systems, heat pumps …, or in energy efficiency to reduce their energy needs.On the other hand, producers and energy services companies invest in equipment to produce, transport and distribute energy such as oil or gas wells, powerplanst, tankers, electric systems."	Rejected. We think the sentence is clear and valid as it stands.	Marc Daras	CentraleSupelecAlumni	France
9557	8	37	8	37	I would delete "(e.g. rooftop solar)" or I would add an example to storage, but it looks wierd a solitaire example	Taken into Account. The Sentence has been revised.	Jaume Gasia	Jose Antonio Romero Polo SA	Spain
84275	8	37	8	46	A forthcomming issue to add for law & regulation is the tension on the structural and fonctional materials (Fe, Cu, Si, Ga,Dy, Nd, Li…), especially for the competition mining/extraction and circularity/recycling. Both are energy-intensive, both have impacts on global pollution but are regional-dependent. Goopolitical issues are expected to switch from the current tension on primary (carbonated) energy to a tension on functional and structural materials (eg: the copper to refine from now to 2050 is roughly the double of the amount extracted from Antiquity in the illustrative future of figure 1...! [O. Vidal, H. Le Boulzec, C. François. Modelling the material and energy costs of the transition to low-carbon energy. Joint EPS-SIF International School on Energy 2017, Jul 2017, Varenna, Italy. 10.1051/epjconf/201818900018.])	Noted. We do not understand how to interpret this comment.	Vincent MAZAURIC	Schneider Electric	France
64231	8	39	8	45	The “challenges associated with ultimate disposal of radioactive waste” are addressed in the European Union through the implementation of national policies via binding Euratom legislation - see "European Commission Council Directive 2011/70/EURATOM establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste", 19 July 2011. At the international level, there is a consensus that the maximum level of passive safety can be obtained through geological disposal. It is believed that the continuous increase in our knowledge through RD&D contributes to increasing confidence in the arguments that demonstrate the safety and feasibility of geological disposal.	Noted. We do not believe this calls for any change to the text.	Georges VAN GOETHEM	Royal Academy of Overseas Sciences (ARSOM - KAOW)	Belgium
79517	8	39	8	45	From experience, the mentionned laws are not often the main to regulate energy systems. I suggest the following: "Some aspects of energy systems are governed by laws and regulations, for ewample energy markets regulations, resilience of the enrgy system constraints or startégic reserve, priority access to the grid or capacities,environmental rules, water management for hydropower and the cooling of thermal power plants, carbon price or emissions trading... On demand side, regulation or company policies on teleworking, urban planning can have an important impact on energy demand."	Rejected. This is a bit too much detail for this section.	Marc Daras	CentraleSupelecAlumni	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
63127	8	40	8	44	Suggest adding "licensing, permitting and siting of energy facilities and infrastructure" somewhere in lines 40-44.	Rejected. We believe the examples already there are sufficiency to make the points.	Jennifer Sklarew	George Mason University	United States of America
37661	8	43	8	44	Reference made to nuclear waste should be accompanied by a reference to solar waste as well. Amount of solar panels do be disposed by 2050 will be very large as already articulated by several agencies.	Noted. No space to include this point.	Ravi B Grover	Homi Bhabha National Institute	India
82301	8	44	8	45	Small comment: teleworking may both increase and decrease emissions: In northern Sweden we see a lot of benefits from teleworking when they decrease the commuting in cars in areas with limited access to public transportation), while teleworking may increase the demand for space heating in other regions (not seen in Sweden - so far).	Noted. No space to include this point.	Anna Krook-Riekkola	Luleå University of Technology	Sweden
11669	8	45	8	46	Energy system mitigation will change the specializations required to work in the energy sector despite will create new job profiles and new professionalities, so as better job opportunities.	Noted. No space to include this point.	CHIARA PUGNALINI	Altran Italy (Energy, Industry, Life Science division), European Commission	Italy
1701	8	46	8	46	Should "will reduce eliminate some" be "will reduce some"?	Accepted. will reduce or (or will be added)	Taoyuan Wei	CICERO Center for International Climate Research	Norway
17477	8	46	8	46	reduce "or"? Eliminate	Accepted	Alaa Al Khourdajie	IPCC	United Kingdom (of Great Britain and Northern Ireland)
20883	8	46	8	46	"reduce eliminate" is an editorial mistake	Accepted	Government of France	Ministère de la Transition écologique et solidaire	France
51043	8	46	8	46	"reduce eliminate": reduce or eliminate	Accepted. Same as above	Eric PROUST	European Nuclear Society (ENS)	France
51317	8	46	8	46	I strongly recommend that the word "will" be changed to "should"; after all, certainty, in this case, depends on planning and effective political-energy actions - that is, equivocal in these plans and actions can mean job losses, and not the expected increase in jobs related to the necessary energy transition. At the very least, this issue should be analyzed with more caution, with more prudence; thus, the word should is the right one in this context - or else, that some small sentence is added in this same Line 46 in order to explain this question of the use of the word wiil, but provided that the energy policies, in fact, contemplate the mitigation of climate change and that are effectively successful ...	Noted	Government of Brazil	Ministry of Foreign Affairs of Brazil	Brazil
63129	8	46			need to add "and" between "reduce eliminate"	Noted	Jennifer Sklarew	George Mason University	United States of America
71521	8	46	8	46	"and" is missing	Notedl	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
81039	8	46	8	46	the word 'reduce' should be removed (leaving "...will eliminate some jobs while creating others")	Noted	Aaron Barkhouse	SunPower Corporation	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
47827	9	1	23	26	This section should at minimum discuss (ideally in a text box with sufficient detail) the impacts and resulting changes due to the COVID-19 pandemic. The effects on the energy systems were presented, for instance, in this recent paper: https://www.nature.com/articles/s41558-021-01001-0	partially accepted . Information has been added on emissions in 2020 as a result of COVID	Patrick Lamers	NREL	United States of America
55603	9	3	9	5	Suggest adding references or dropping. There is a larger social sciences literature.	Noted	Government of United States of America	U.S. Department of State	United States of America
81041	9	4	9	4	remove the words 'energy in'	Accepted	Aaron Barkhouse	SunPower Corporation	United States of America
9559	9	9	9	9	I would change "homes" by either "buildings" or "households"	Accepted	Jaume Gasia	Jose Antonio Romero Polo SA	Spain
1703	9	11	9	11	Should "assess energy" be "assesses energy"?	Noted	Taoyuan Wei	CICERO Center for International Climate Research	Norway
9561	9	11	9	11	modify "assess" by "assesses"	Noted	Jaume Gasia	Jose Antonio Romero Polo SA	Spain
81043	9	11	9	11	change 'assess' to 'assesses'	I can't locate this comment	Aaron Barkhouse	SunPower Corporation	United States of America
775	9	12		34	Why is not possible to tackle the power industry? What are those debacle (failure points) that impede the development of energy systems?	several sections are devoted to the power industry for instance 634, 637, 645 energy transport and distribution	Alok Dhaundiyal	Szent Istvan University	Hungary
85473	9	12	23	26	This is an unordered grocery list of bad news. I'm not advocating changing the facts but if you want people to understand what you are saying you should have a clear narrative. And if you not only want to present the problem and make them anxious, but also want to give them hope and perspective, you should point to solutions. So don't just shout 'fire' but also point them to emergency exit. And to those who say "If we say how bad it is, people will be forced to change!" I say: you talk to much with people in a peer group that contains 0.01% of the world population. Most people will just shrug and take up something else where they understand how they can make a positive difference. So you have to go the extra mile: not just sum up all the reference but provide guidance and insight and knit it together in a way that makes sense and leads somewhere.	Rejected. Policy relevant solutions are presented in the whole chapter.	Auke Hoekstra	Eindhoven University of Technology	Netherlands
779	9	13	10	10	I have noticed that the land contamination is not being discussed. Could the CO2 has an impact on land during geological storage? Landfilling and radio active disposal might affect the land despite they have least impact on the air quality. Discuss it succinctly.	Rejected. Policy relevant solutions are presented in the whole chapter.	Alok Dhaundiyal	Szent Istvan University	Hungary
17203	9	13	9	13	Section 6.3.1 draws from a single data source to describe emissions trends (EDGAR - the main source used in ch2 and other sector chapters). A useful contribution would be to compare several sources of energy system emissions (e.g. https://www.che-project.eu/data-portal), and include some text on the range of these estimates. One could also compare earlier years against AR5. This would be an important quality check on the results shown here and elsewhere. It would be especially important for non-CO2 emissions sources (alluded to on p12, line 3-10, but not fully developed). Ch7 (AFOLU) does this for Agricultural and LULUCF emissions (see section 7.2.1).	Rejected. Space constraint. Comparing different sources with different methodologies will imply much more space. Further recommendation is to use EDGAR. IEA source was used when EDGAR not relevant, i.e emissions by sources	William Lamb	Mercator Research Institute on Global Commons and Climate Change (MCC)	Germany
81045	9	15	9	18	This note needs to be revised for clarity - possibly should refer to 'energy generation, conversion, and transmission' on line 15/16, and line 18 needs revision too.	Accepted- but not the suggested definition	Aaron Barkhouse	SunPower Corporation	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
84277	9	15	9	18	The relevant perimeter to discuss of the stability of the power system is the "full energy system" in order to leverage in real-time all the connected assets (e.g. the motor of a lift - and subsequently the lift embedded weight - contributes to the inertia of the whole power system whereas it clearly belongs to the demand!)	Rejected. Stablity of energy system not the purpose of this paragraph and followings.	Vincent MAZAURIC	Schneider Electric	France
771	9	16			except for or except / available energy in place of final energy	Accepted. Will be replaced by except for.	Alok Dhaundiyal	Szent Istvan University	Hungary
43533	9	19	9	34	Some reference to the methods used for accounting emissions and possibly, aggregating them across sources would be useful. If this is done in another chapter please recall it	Rejected.Sources for GHG are explicity mentioned.	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy
43845	9	19	9	22	To better emphasize the point of this paragpraph, compare the decadal percentage increases of fossil fuel-induced GHGs. A good reference (to cite) for this is the recently published Global Carbon Budget 2020 by P. Friedlingstein et al. [4].	Rejected. Fig 6.2 sufficient to capture GHG trend..	Vince Davidson Pacañot	University of the Philippines Diliman	Philippines
79519	9	19	9	19	The first sentence could be suppress beacuse the 2°C limit does not depend only of energy system. Then, since on the 2 follonwing § could we start by. "As it concerns CO2 emissions,..." Because lien 4 p 10 goes on global GHG and there is no continuity.	Accepted to be reformulated. Current emissions trends, if continued, are not sufficient to contribute to limiting etc...	Marc Daras	CentraleSupelecAlumni	France
61957	9	21	9	26	Improve sentences "Global energy system fossil fuel CO2 emissions grew at an average compounded annual rate of 1.3% yr-1 between 2010 and 2019 reaching a high of 38 GtCO2 yr-1, and accounting for approximately two-thirds of annual global anthropogenic emissions (Figure 6.2). Coal was the single largest contributor to emissions between 2010 and 2018, accounting for about 45 % of emissions. Oil accounted for about 35% of emissions, and natural gas accounted for about 20%. Coal, oil and natural gas CO2 emissions grew respectively at annual rates of 0.37% yr-1, 0.44% yr-1 and 0.89% yr-1." as 1.3% yr-1 does not add up with "0.37% yr-1, 0.44% yr-1 and 0.89% yr-1" and still it should be the product of the last three something does not make sense.	Accepted. Figures will be checked and explanation provided	Esa Vakkilainen	LUT University, Lappeenranta	Finland
79521	9	21			Suppress" energy system" to avoid confusion. Nota: 36 GtCO2 from GCP, but I guess a global metric is used throughout the report.	Accepted. reformulated as follows to match our diefinition: CO2 emissions from the full energy system	Marc Daras	CentraleSupelecAlumni	France
17189	9	23	9	34	It would be important to align these numbers with Ch2 (e.g. Figure 2.13). As of SOD, and accounting for total GHG emissions, electricity and heat is 24% of total. Industry is 23% (direct), transport is 14%. These numbers will change before the final draft, due to data updates and new GWPs from WG1.	Accepted.Figures have been aligned with chapter 2 based on latest data in DMS from chap2	William Lamb	Mercator Research Institute on Global Commons and Climate Change (MCC)	Germany
17899	9	23	9	34	Seems a sector is missing from the emissions - buildings?	Accepted. A couple of sentences will be added to include buildings	Robert Brecha	Climate Analytics	Germany

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
84279	9	23	9	34	After one century of worldwide implementation of electricity (and subsequent research & development), there is a contradiction to promote electricity for decarbonation of the energy system whereas the actual contribution of the power system counts for 45% of global CO2 emissions (line 24) ! Despite of this up-to-date achievement, a fundamental justification to expect a possible decarbonation of the power system relies on the thermodynamic reversibility trend of the electromagnetic conversion [e.g.: V. Mazauric, "From thermostatistics to Maxwell's equations: A variational approach of electromagnetism," IEEE Transactions on Magnetics, vol. 40, pp. 945-948, 2004; or: X. Li, N. Maïzi, and V. Mazauric, "A lattice-based representation of power systems dedicated to synchronism analysis," International Journal in Applied Electromagnetics and Mechanics, vol. 59, pp. 1049-1056, 2019.]	Rejected. Trends show that renewable electricity will play an important role in decarbonisation of the full energy system (renewable power plants, transport etc.)	Vincent MAZAURIC	Schneider Electric	France
85471	9	23	9	26	You've just stated that the global energy system accounts for 2/3rds of emissions but you have not explicitly stated that you are now talking about how this 2/3rd is divided. I would start the paragraph with: "Zooming in on the energy system, coal was the single largest contributor..."	Accepted	Auke Hoekstra	Eindhoven University of Technology	Netherlands
55605	9	26	9	29	If covering the sources of CO2 emissions, why leave buildings out?	Accepted. A couple of sentences will be added.	Government of United States of America	U.S. Department of State	United States of America
74771	9	26	9	28	Since GHG emissions from the industrial sector is also captured in this section using 'industry' (i.e. ....followed by industry at 22%), the sentence shouldn't have been introduced with "The power industry remains..........." but rather for instance as "The power sector remains..............".	Accepted.	Semilore Abikoye	Department of Chemical Engineering, University of Cape Town	South Africa
74843	9	26	9	26	consider adding the word respectively after "0.89% yr-1".	Accepted.	Government of Kenya	Kenya Meteorological Service	Kenya
85375	9	26	9	26	Same comment as for the Ch4, p 78, l 17 - with the presented shares of the emission, what would be definition for the "high emitting sector".	Comment not specific to our chapter. There is no mention of high emitting sector in this line	Neil Dickson	ICAO	Canada
74773	9	27	9	28	I quite agree with this report that the account of GHG emissions mostly overlook tne shipping and aviation sector. Thus, instead of using "international shipping and aviation transport", I will rather suggest that it should just be "shipping and aviation transport" without including the word "international"	Rejected. The figures quoted are on international shipping and aviation transport. Deleting the world international will be misleading as we need to including domestic flights and aviation	Semilore Abikoye	Department of Chemical Engineering, University of Cape Town	South Africa
20885	9	28	9	29	This figure is lower than the estimate given in Chapter 10: Transport because it is an estimation about international transport only. The total percentage of CO2 emissions for these sectors could also be specified. "The aviation and shipping sectors are currently approximately 5 per cent of global annual CO2 emissions 11 (Faber et al., 2020)" "The latest available data (2018) indicate that aviation is responsible for approximately 2.4% of total anthropogenic emissions of CO2, including land use change, on an annual basis (using IEA data, IATA data and global emissions data of Le Quéré et al., 2018)." "Shipping (international combined with domestic and fishing) emitted 1.06 Gt CO2 in 2018, which is an increase of 10% from 2012, accounting for 2.9% of global anthropogenic CO2 emissions (Smith et al., 2014, Faber et al., 2020)"	Rejected. The figures are for international shipping and aviation. The % is against GHG emissions and not CO2. Against CO2 emissions the figure will be higher. The percentage quoted and the evolution is the share of international shipping and aviation against all GHG emissions in the full energy sector. The figure (3.3%) is not an increase of aviation and shipping.	Government of France	Ministère de la Transition écologique et solidaire	France
61959	9	28	9	28	Typo: change "Shipping and aviation international" to "International shipping and aviation"	Accepted.	Esa Vakkilainen	LUT University, Lappeenranta	Finland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
74775	9	29	9	29	"These relative proportions have remained relatively unchanged". My comment here is on the use of relative in combination with relatively unchanged". I will suggest that either relative or relatively should be replaced with other matching word	Accepted. The first relative will be deleted	Semilore Abikoye	Department of Chemical Engineering, University of Cape Town	South Africa
81047	9	29	9	29	Change aviation international to international aviation.	Accepted. Both relative and relatvely can be deleted.	Aaron Barkhouse	SunPower Corporation	United States of America
82087	9	30	9	33	Although it is true that the energy sector still has to face a lot of challenges, it would be interesting to know the regions or sectors where there have been improvements. This is not mentioned here or in the rest of the subsection. In the same way, although the title of the subsection mentions that the rate of increase continues to decline, that is not mentioned in the rest of the subsection.	Rejected. Figure 63 top right is about sectors and bottom right is about regions. No need to comment. Space constraint	Sofia Rosero Abad	University	Netherlands
1083	9	31			the rapid deployment	Accepted	Alok Dhaundiyal	Szent Istvan University	Hungary
17321	9	31	9	31	"…rapid deployment…" Unfortunately wind and solar deployment is not rapid. Many other sources in the history were deployed faster (even in the less wealthier World). Fossile sources are being deployed faster even today (natural gas, and oil).	Rejected. Growth rate of solar and wind are extremely high	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
28397	9	31	9	31	The report states power sector emissions continue to rise, which is of course true. However, add to this how in many regions power sector emissions start to decline, opening up possible pathways for other parts of the world to follow.	Rejected (same as 82087) Figure 63 top right is about sectors and bottom right is about regions. No need to comment. Space constraint	Naud Loomans	Eindhoven University of Technology	Netherlands
78495	9	31	9	31	"…rapid deployment…" Wind and solar deployment is not rapid. Many other sources in the history were deployed faster (even in the less wealthier World). Fossile sources are being deployed faster even today (natural gas, and oil). Nuclear was developed faster in Sweden and France and in some other countires also.	Rejected. Figures show without any doubt that there is a rapid deployment of wind and solar.	Tomaž Žagar	Faculty for Energy Technology, University of Maribor	Slovenia
79523	9	31			"despite 16% of hydro electricity and the rapid depoyement of wind and solar power. However, the later represent only 5% and 2% respectively of the total electricity production".	Rejected. Space constraint. 635 addresses the issue of capacity and electricity generation	Marc Daras	CentraleSupelecAlumni	France
74777	9	33	9	34	In my opinion, it may not be enough to state that "Some specific sectors, such as shipping and aviation may present long-term challenges". However, in addition to the sentence, it will be good to add a line or two on the reason to substantiate this claim	Accepted. We can add because of viable, commercial and cost-effective options will take several years to be deployed on a large scale	Semilore Abikoye	Department of Chemical Engineering, University of Cape Town	South Africa
79525	9	33			The reference to electric car is improper here beacause 1: it is outside the scope of the energy supply system; 2: theref. 6.3.7 refers to stationary battery and storage for balancing the variability of the production.	Rejected. The section is about the full energy system and not only on energy supply.	Marc Daras	CentraleSupelecAlumni	France
777	10	1			what does this 'yearly change' demarcate? CO, NOx, SO2, CH4, CO2 ….or what	Accepted. Figure amended	Alok Dhaundiyal	Szent Istvan University	Hungary
781	10	1		10	How do the author(s) see the waste management in the context of energy system trends?	Rejected. Beyond the scope of chapter	Alok Dhaundiyal	Szent Istvan University	Hungary
1705	10	1	10	1	In the figure 6.2, it is unclear which point corresponds to 38,017, 33.971 and 25,700. it might also be good for a reader if you mention that the right Y-axis is for yearly change and the left one for total emissions.	Accepted for both (figures and axis)	Taoyuan Wei	CICERO Center for International Climate Research	Norway
9563	10	1	10	1	I strongly recommend not displaying figures made by Excel in official reports, since other open source sources are available of making more professional figures. I also recomend homogeneizing styles of figures, in order not to show hetereogeneity	Accepted but guidance needed from TSU.	Jaume Gasia	Jose Antonio Romero Polo SA	Spain

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
12469	10	1	11	18	Emission data up to 2020 have been published https://www.iea.org/articles/global-energy-review-co2-emissions-in-2020	Accepted. Last figures will be compiled	Philippe Quirion	CNRS	France
85957	10	1	10	3	Figure 6.2. Consider presenting the annual CO2 emission change data on the secondary y-axis as a percentage of emission levels in the previous year.	Accepted	Government of Australia	Department of Industry, Science, Energy and Resources	Australia
17191	10	4	10	10	As in the previous comment, these numbers (and figure 6.3) could be aligned with Ch2. There would also be a good argument for having a consistent set of cross-sector chapter figures and data here. Such figures have been produced and circulated via the TSU. These show, for example, the regional trends by subsector. Also note that the WG3 emissions data is on DM, with a specific set of subsectors for the energy systems sector developed and documented in Annex B, and with the current GWPs embedded. I do not recognise the sector aggregation shown in the top right panel of 6.3.	Accepted. Fig top right 6.3 will be checked. All figures aligned with chapt 2.	William Lamb	Mercator Research Institute on Global Commons and Climate Change (MCC)	Germany
43847	10	4	10	10	For the greenhouse gas emissions, a figure showing emissions (in ppm) of different highly-potent hreenhouse gases (CO2, CH4, N2O) could be included. A suitable reference would be the November 2020 GHG Bulletin of thw World Meteorological Organization [5].	Rejected. space constraint.	Vince Davidson Pacañot	University of the Philippines Diliman	Philippines
43849	10	4	10	17	According to Le Quéré et al. (2020) [6], there has been a significant decrease in GHG emissions during the enforced lockdowns due to the pandemic. If we will factor in the COVID-19 pandemic in this chapter, it could be cited as a contributing factor to the emissions drop. Note that the report also mentioned that decarbonizing some sectors(e.g. transport) could be advantageous in the global attempt to reduce GHG emission.	Rejected. 2020 figures are not considered There are also paragraphs on COVID	Vince Davidson Pacañot	University of the Philippines Diliman	Philippines
78459	10	5	10	6	After the sentence "Approximately 20% of energy supply emissions were non-CO2 emissions, particularly methane as fugitive emissions in oil, gas, and coal operations." add: "These contribute to nearly half of total methan emissions [Reference: Höglund-Isaksson, L., Gómez-Sanabria, A., Klimont, Z., Rafaj, P. & Schöpp, W. Technical potentials and costs for reducing global anthropogenic methane emissions in the 2050 timeframe –results from the GAINS model. Environ. Res. Commun. 2, 25004 (2020). https://doi.org/10.1088/2515-7620/ab7457].	Accepted. Suggestion will be checked	Pietro Altermatt	Trinasolar, Changzhou, China	Germany
17323	10	9	10	10	"This growth has occurred despite the high penetration of solar PV and wind utility-scale power plants particularly in Asia and developed countries." According to BP, 2020 statistics, I would not say that penetration of wind and solar PV was high - especially not in comparison with fossil fuels.	Accepted.	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
61751	10	9	10	10	"This growth has occurred despite the high penetration of solar PV and wind utility-scale power plants [..]". The penetration of these technologies in the electricity sector remains low, at 9% total as stated on page 4 line 19. The addition of these technologies can be considered only moderately high and only in comparison to additions in other low-carbon generation: During 2013-2019 the annual production grew in hydro 408 TWh, solar 584 TWh, and wind 795 TWh (https://ourworldindata.org/renewable-energy) and nuclear energy grew by 303 TWh (BP Energy Statistics 2020). At the same time the annual fossil fuel use grew by 8312 TWh.	Accepted. Will be reformulated. Could be despite the high growth rate.	Rauli Partanen	Think Atom	Finland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
65785	10	9	10	10	"This growth has occurred despite the high penetration of solar PV and wind utility-scale power plants [..]". The penetration of these technologies in the electricity sector remains low, at 9% total as stated on page 4 line 19. The addition of these technologies can be considered only moderately high and only in comparison to additions in other low-carbon generation: During 2013-2019 the annual production grew in hydro 408 TWh, solar 584 TWh, and wind 795 TWh (https://ourworldindata.org/renewable-energy) and, in China, nuclear grew by 250 TWh. At the same time the annual fossil fuel use grew by 8312 TWh. Revise accordingly.	Accepted. will be refomulated. However in relative values, growth is very high.	Eero Hirvijoki	Aalto University	Finland
78461	10	9	10	10	"This growth has occurred despite the high penetration of solar PV and wind utility-scale power plants". It is unclear what you mean with high prenetration. If you mean the annual rate (of 11.5% mentioned in line 18 on p. 13), it is better write "… despite the high growth rate of solar PV and wind..."; if you mean their share, this statement is in contradition to line 18 on p.13 (2%).	Accepted. Same as above. Will be replaced by despite the high growth rates	Pietro Altermatt	Trinasolar, Changzhou, China	Germany
79527	10	9	10	10	Could be suppress beacuse already said on p9. The term penetration is improper because in total they represent 7% of total production 2019. AIE. The term "investment" is more relevant.	Accepted. Same as above. Will be replaced by despite the high growth rates	Marc Daras	CentraleSupelecAlumni	France
81049	10	9	10	10	Claiming there is 'high penetration' of wind and solar PV can be misleading without context. While they represent an increasingly significant fraction of new power generation, the overall penetration rate of wind and solar as a share of total/cumulative installed energy generation remains modest even in most developed countries (typically <20% in terms of total energy output in kWh/yr).	Accepted. Will be reformulated. Could be despite the high growth rate.	Aaron Barkhouse	SunPower Corporation	United States of America
2629	10	10	11	3	Emissions by Fuel: Why do you fit a straight line to coal (doesn't look linear), and why do you not fit something to natural gas or oil (which looks much more linear)?	Accepted. To avoid any misunderstanding, line to coal will be taken out	Jan Wohland	ETH Zurich	Switzerland
2631	10	10	11	3	Emissions by sector subfigure is really hard to understand. Is "int. aviation & shipping" a sub-category of "transport"? This is not clear.	Accepted. Figure might be redesigned although it is clear from the figure that international shipping and aviation is not part of the transport. Power sector includes electricity and heat	Jan Wohland	ETH Zurich	Switzerland
2633	10	10	11	3	Subfigure on GHG emissions by fuels of energy supply system does not speak for itself. I find it difficult to understand what this figure says. For example, how is "electricty & heat" a fuel of the energy supply system?	Accepted. Same as above	Jan Wohland	ETH Zurich	Switzerland
18217	10	10	10	10	The graphs would be easier to interpret and understand with Y-Axis labels showing units	Accepted. Units will be added with Y labels	Government of United Kingdom (of Great Britain and Northern Ireland)	Department for Business, Energy & Industrial Strategy	United Kingdom (of Great Britain and Northern Ireland)
20887	10	10	11	1	(editorial comment) On the block in the lower right corner of figure 6.3, we suggest to better place the name of the continents within the dedicated colored part.	Accepted. Figure redesigned.	Government of France	Ministère de la Transition écologique et solidaire	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
64593	10	10	11	3	Some elements in Figure 6.3 are unclear and unhelpful. In the top left panel there is a linear line "linear (coal)" inserted, which serves no purpose than to send the wrong message, namely that coal use levelled off since 2010. No similar trend lines are shown for oil and gas, thankfully, so suggest to delete this line. In the bottom left panel the biggest category label is "electricity and heat", but those are not the source of the emissions, and look odd in comparison with the other categories in the panel. What is meant here: fossil fuels for electricity&heat production? Correct accordingly.	a) Accepted to delete line for coal. b) asterisk might be added to specify fuels for electricty generation. It is not fossil fuels but all fuels.	Government of Netherlands	Ministry of Economic Affairs and Climate Policy	Netherlands
71523	10	10	10	10	"in Asia and developed countries": it is not clear what exactly that means - in developed Asian countries? In Asian countries and developed countries elsewhere?	reformulated in most Asian and developed countries	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
85959	10	10	11	3	Figure 6.3. Suggest would be more readable with aligned and harmonised axes.	Accepted- figure redesigned	Government of Australia	Department of Industry, Science, Energy and Resources	Australia
783	10			10	Fugitive emission is one the main concerns, but why the govt. promote CBM or coalseam and shale gas extraction schemes?	IPCC policy is not to be prescriptive. In the whole document relevant policy measures are addressed	Alok Dhaundiyal	Szent Istvan University	Hungary
785	10			11	axes labels are missing fig 6.3	Agreed. Not properly copied from word. Sorted out. Figure has been updated	Alok Dhaundiyal	Szent Istvan University	Hungary
27709	10		10		Figure 6.2: specify which data are presented in the LHS and RHS axes.	Accepted. This will be added in redesigned figure	Eleni Kaditi	Organization of the Petroleum Exporting Countries, OPEC	Austria
60133	10				Units are missing in the Y-axis Is it per unit volume ?	Agreed.. Sorted out. Figure has been updated	Umasankari Kannan	Bhabha Atomic Research Centre	India
1707	11	1	11	1	Is there any difference between "global energy-related CO2 emissions" and "global energy GHG emissions" besides the included pollutants? Is "global energy-related CO2 emissions" the same as "global energy CO2 emissions"? In addition, in all the panels of Figure 6.3, the starting year is 2000, not as stated in the caption "1990-2018"!	Accepted caption will be amended. Glossary includes defintion of CO2 and GHG. No need to define here	Taoyuan Wei	CICERO Center for International Climate Research	Norway
43535	11	1	11	3	Caption unclear, remove "top left" , explain linear coal trend in top left panel	Accepted. Caption will be amended	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy
64121	11	1	11	2	Data plotted in Figure 6.3 is for the period 2000-2018. However, figure title mentions plotting period 1990-2018.	Accepted. Caption will be amended	Ghulam Rasul Athar	Pakistan Atomic Energy Commission	Pakistan
64123	11	1	11	2	Figure title is for two top figures. The title should cover all four figures.	Accepted. Caption will be amended to cover 4 fgures	Ghulam Rasul Athar	Pakistan Atomic Energy Commission	Pakistan
78549	11	1	11	1	The title of Figure 6.3 should represent the 4 presented pictures; e.g.: Figure 6.3 Global energy-related CO2 Emissions in MtCO2 yr-1 (Top left: by Fuel) (Top right: by Sector) and Global energy GHG emissions in GtCO2-eq yr-1 (Bottom left: by fuels of energy supply system); (Bottom right: Distribution by region)	Accepted	MAMADOU LAMINE DOUMBIA	University of Quebec	Canada
82303	11	3	11	3	One "ending bracket ")" is missing.	I can't locate this comment	Anna Krook-Riekkola	Luleå University of Technology	Sweden
787	11	4		17	wordy sentences (In the case of EU, This is especially the case in the Asian economie, In Europe and North America) Rewrite the whole paragraph	Comment not explicit. It does not seem to relate to the content of the text	Alok Dhaundiyal	Szent Istvan University	Hungary

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
1711	11	4	11	17	It is unclear how many drivers you have considered although it becomes clear in Figure 6.4. It would help a lot to mention all the key drivers you consider: Population, GDP per capita, energy intensity and carbon emissions per unit energy use. Perhaps also mention the decomposition method.	Accepted. After per capita we may add between brackets (fig 64). As mentioned fig 64 shows very clearly the drivers.	Taoyuan Wei	CICERO Center for International Climate Research	Norway
2635	11	4	11	9	This sounds as if you argue that population growth (l. 8) is the reason why “global energy system CO2 emissions have closely tracked GDP per capita” which sounds contradictory because GDP per capacity is to first order independent of population. I think this line of reasoning needs more clarity.	Rejected. First sentence clearly states that GDP per capita is a key driver.	Jan Wohland	ETH Zurich	Switzerland
10913	11	4	11	17	The content is too dificult to understand. I recommend to insert the Kaya Identity in explanation. Then the readers can understand the content easily	Rejected. No need to insert Kaya identity	Dong-Woon NOH	Korea Energy Economics Institute	Republic of Korea
16337	11	4	11	17	The content is too dificult to understand. I recommend to insert the Kaya Identity in explanation. Then the readers can understand the content easily	Same as above	Government of Republic of Korea	Korea Meteorological Administration (KMA)	Republic of Korea
20889	11	4	11	5	Not really consistent with the 'decoupling' statement in the executive summary	There is no contradiction with ES	Government of France	Ministère de la Transition écologique et solidaire	France
20891	11	4	11	5	This sentence does not really seem to be consistent with 'decoupling' statement in the executive summary	Same as aboveThere is no contradiction with ES	Government of France	Ministère de la Transition écologique et solidaire	France
64397	11	4	11	4	It would help the reader to define energy intensity and describe why this is important.	Energy intensity is defined in the glossary (to be checked)	Curt Bjurlin	Stantec Consulting	United States of America
64595	11	4	11	5	Unclear what "closely tracked" implies here, looks at odds with the observed energy intensity decline.	Accepted. This will be checked and reformulated if needed.	Government of Netherlands	Ministry of Economic Affairs and Climate Policy	Netherlands
79531	11	4	11	17	This § relates to the global energy system., while the precedent is on the energy supply. It could be moved directly after page 9 in order to keep consistency of topics.	This will be considered	Marc Daras	CentraleSupelecAlumni	France
71525	11	6	11	7	are there no more up-to-date papers on economic growth in Asia? 2014 and 2014 seems a bit outdated.	Accepted, recent reference will be added	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
74779	11	8	11	9	"Population growth is also a contributing factor globally and in most regions particularly Africa, albeit to a significantly lower extent than economic growth". This may not be completely true for the entire continent of Africa. It could have sub-regional specific (e.g sub-Saharan african) or at best to give examples of countries which should again be appropriately referenced to substantiate the claim.	Rejected.There might be some differences within African countries sentence is valid for the whole of Africa.	Semilore Abikoye	Department of Chemical Engineering, University of Cape Town	South Africa
52151	11	12	11	14	The reduction in CO2 emissions in Europe and North America may also be due in part to offshoring, i.e., having energy intensity industries located outside those regions and their products imported into them.	We need to check in other chapters whether offshoring has been addressed	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
12193	11	14	11	17	The significant decrease of GHG emissions in Europe is also due to the steady output of nuclear power capacity, especially after the Fukushima accident and the annoucement of Germany to retire its nuclear fleet. The Latest World Nuclear Performance Report 2020 published by the World Nuclear Association shows the significant contribution of nuclear power in Europe. Nuclear power represents 50% of the low carbon energy generated in the EU and about 30% of the entire production. We believe that this paragraph should also reflect the continous contribution of nuclear power as the backbone of the low carbon energy transition efforts.	To be checked whether share of nuclear has increased in the last decade. Percentages given in the comment might be misleading as they don't show the trend.	Lavinia Rizea	SN Nuclearelectrica SA	Romania
84281	11	14	11	17	The statement of the CO2 mitigation in EU due to renewable implementation since 2010 is very questionable. Without neglecting the role of renewable generation especially in Germany, the key driver for emission reduction is the removing of energy-intensive industries following the post-2008 crisis. As matter of fact, the CO2 emission has decreased, whereas the carbon footprint (including the leakages at the EU borders) has increased [see video given by two french ministers for environment and industry: http://www.uniden.fr/vag2020.htm].	Accepted. Removing energy intensive industries will also be considered. However other ref will be considered.	Vincent MAZAURIC	Schneider Electric	France
79529	11	17			It could be added " the decrease in US is due to the replacement of coal power plant to natural gas power plant, following the production from unconventional gas and oil.	Accepted if referenced.	Marc Daras	CentraleSupelecAlumni	France
1709	12	1	12	2	Difficult to understand the figure. It would be helpful to mention that the 1990 level is 1, the label in the end of each curve is yearly change rate over the period? What do you mention by the legends, e.g., is "energy_GDP" the energy intensity or energy-related GDP, is "GDP_POP" the GDP per capita or total population, and is "POP" refering labor-aged population or total population? Please make it clear. In addition, no data source is provided.	Accepted. Might be redesigned	Taoyuan Wei	CICERO Center for International Climate Research	Norway
2637	12	1	12	3	This Figure is largely unclear to me. I assume that the different colors denote the components of the Kaya intensity so that CO2_energy would denote CO2 emissions divided by energy demand, normalized to 1990 values. This should be stated explicitly somewhere. Moreover, I do not understand the meaning of the numbers given in the subplot. For example, in Africa, CO2_energy in 2018 seems to be "-1.1%" while energy_GDP is "-0.4%" even though the plot suggest that the amplitude of the latter is substantially larger than the former. And what do these numbers mean? Are these differences between 1990 and 2018 (in which case the graphs really don't match the numbers)? The more I look at the Figure, the more I think that something went completely wrong here. In the middle east, CO2 has increased almost 4 fold, but the percentage says 1.5%...	Accepted. Might be redesigned	Jan Wohland	ETH Zurich	Switzerland
15085	12	1	12	1	It is suggested that the vertical coordinates of each region should be consistent in Figure 6.4, so that readers can accurately understand the differences in each region. In addition, there is a lack of illustration, so it is suggested to add the meaning of the description curve.	Accepted. Further explanation will be added. However vertical coordinates will stand. Reference to article will be added	Guoquan HU	National Climate Center of China Meteorological Adminstration	China

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
17193	12	1	12	1	What is the source for this Kaya figure? What is the exact system boundary (energy systems sector, energy supply, or all sectors)? What is the underlying data?	Accepted. to be sorted out with chapter 2.	William Lamb	Mercator Research Institute on Global Commons and Climate Change (MCC)	Germany
43537	12	1	12	1	The caption to Figure 6.4 is inaccurate. The graphs depict CO2 emission trends (green data points) and the factors explaning their changes (other colors). note that axes' labels are missing, please add them.	Accepted. Might be redesigned	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy
45467	12	1	12	1	The legend could be improved. Say e.g. CO2/energy. Furthermore, please specify what energy is meant (e.g. total supply or final) and what GDP (e.g. PPP corrected or not)	Accepted	Kornelis Blok	Delft University of Technology	Netherlands
47037	12	1	12	1	It might help to have a more detailed description of the figures (i.e. what the percentages mean).	Accepted	John Leo Algo	Living Laudato Si' Philippines	Philippines
53721	12	1	12	2	Figure 6.4 lacks a figure description. The meaning of the curve needs to be described.	Accepted	ZHENG XINZHU	China University of Petroleum (Beijing)	China
64125	12	1	12	1	In Figure 6.4, graphs are not cleared/ correct. i.e., in bottom left (graphs for southern Asia), growth rates of CO2 emissions and GDP/capita are same in 2018 (5.3%) but plotted values are at different places. Furthermore, the figure is not referred in text.	Accepted	Ghulam Rasul Athar	Pakistan Atomic Energy Commission	Pakistan
64599	12	1	12	2	Figure 6.4 is difficult to read or interprete. Provide explanations in an extended caption, including: what is the unit on the vertical axis? What are the precentage values provided for each curve? How is it possible that curves with the same percentage end up at very different levels, for example 2x 5.3% for Southern Asia, but they end up at levels 3.3 and 5.3 by 2018. Without better explanantion and discussion this graph makes no point and should be dropped.	Accepted	Government of Netherlands	Ministry of Economic Affairs and Climate Policy	Netherlands
85961	12	1	12	2	Figure 6.4. Can the data series "energy_GDP" and "GDP_POP" be explained (perhaps in the figure caption).	Accepted	Government of Australia	Department of Industry, Science, Energy and Resources	Australia
86521	12	1	12	1	Fice 6.4 key - unitis are not clear. Presumably "GDP / population , energy / population" etc. energy_pop does not convey the intended meaning	Accepted	raphael Slade	Imperial college	United Kingdom (of Great Britain and Northern Ireland)
791	12	2		15	anthropogenic emission??? Missing (it is around 60% of 570 million tonnes)	Rejected. Figures are correct although might be slighly revised with new release by EDGAR	Alok Dhaundiyal	Szent Istvan University	Hungary
793	12	2		15	There remains a high degree of uncertainty in methane emissions? Refer Methane and climate change 'Methane tracker'	Rejected. Uncertainty is addressed	Alok Dhaundiyal	Szent Istvan University	Hungary
17325	12	2	12	2	Fig 6.4 would be more valuable, if population size (number) is given next to each chart so that reader has an impression about the weight of each chart in the total World picture.	Accepted	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
61961	12	2	12	2	Typo: Figure 6.4 missing vertical axis value for all	Accepted. Figure redesigned with valued on vertical axes	Esa Vakkilainen	LUT University, Lappeenranta	Finland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
17195	12	3	12	10	It would be very important to align these numbers with Ch2 before the final order draft, because there were very substantial changes by working group 1 to the global warming potentials for fugitive methane sources.	Accepted. Last data posted by chapt 2 will be used	William Lamb	Mercator Research Institute on Global Commons and Climate Change (MCC)	Germany
19193	12	3	12	6	Important to note a high level of uncertainties regarding methane emissions levels. Most of top-down approaches can differ from bottom-up approaches by a factor of 2. bottom-up approaches require installations of infrared cameras, drones, and a better inventorisation system. This observation is important because methane emissions inventorisation and incentives on methane emissions reduction will be amongst core policy priorities. The EU methane emissions strategy is the first step in this direction, see Andrei Belyi, EU Methane emissions strategy: European ambitions, global challenges, Gas Transitions-Natural gas World, 23 November 2020	Rejected. Uncertainty in methane emissions is addressed. see ref.	Andrei Belyi	University of Eastern Finland	Finland
45881	12	3	12	10	Please add more information about methane emission, e. g. methane slip from engines. Methane slip is the emission of unburnt methane in gas engines. Methane slip usually lies between 0.5 and 3 % of the combusted methane-containing fuel and has an important impact on the GHG emissions of the installation. Literature: UBA-Hintergrundpapier "Biogasanlagen - sicherheitstechnische Aspekte und Umweltauswirkungen, page 8 https://www.umweltbundesamt.de/sites/default/files/medien/376/publikationen/2019_04_10_uba_hg_biogasanlagen_bf_300dpi.pdf; Wachtmeister, G: Ursachen und Reduzierung der CH4-Emissionen von Biogasmotoren, Technische Universität München 2016; Olthuis, H. J., Engelen, P. A. C: Overzichtsrapportage Emissieonderzoek methaanemissies bij gasmotoren op continue vollast, KEMA Nederland B. V., Arnhem 2007	Rejected. Space constraint.	Government of Germany	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety International Climate Policy	Germany
51341	12	3	12	6	only 82 Mt methane from oil and gas but described as primary component of over 2.5 Gt?	Rjected. This is correct. 1 ton CH4= around 30t CO2eq.	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
64281	12	3	12	10	Several studies are highlighting the higher-than-expected fugitive methane emissions from the oil & gas sector, and the use of satellite imagery to improve methane inventories is becoming more widely acknowledged. The IEA, the world reference for energy related statistics, updated its Methane Tracker in January 2021, incorporating data on large-scale methane leaks detected by satellite (https://www.iea.org/reports/methane-tracker-2021).	Accepted. Could be added	Christian Lelong	Kayrros	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
64283	12	7	12	10	A large part of this uncertainty can be reduced using available technology, in particular monitoring satellites. Rather than relying on emission factors and estimates from energy producers, regulators can measure directly the full amount of methane emissions. For instance, a 2020 study shows the discrepancy between satellite measurements and government estimates of methane emission from a large US oil basin (https://advances.sciencemag.org/content/6/17/eaaz5120). The task force on national greenhouse gas inventories already mentioned the potential for satellite technologies in their 2019 Refinement of 2006 Guidelines (see in particular section 6.10.2 in Volume 1, chapter 6: https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/1_Volume1/19R_V1_Ch06_QA_QC.pdf), insisting on the fact that methane estimates are quite uncertain and could be verified against satellite data. The International Methane Observatory and the EU Methane Strategy are likely to accelerate the shift towards accurate and trusted emissions data.	Accepted. Same as above. A couple of sentences could be added. A large part of this uncertainty can be reduced using available technology, in particular monitoring satellites. The IEA,updated its Methane Tracker in January 2021, incorporating data on large-scale methane leaks detected by satellite (https://www.iea.org/reports/methane-tracker-2021).	Christian Lelong	Kayrros	United Kingdom (of Great Britain and Northern Ireland)
43851	12	12	12	13	I would like to emphasize a caution with regard to citing a report by a petroleum company such as BP. Citing reports by companies as such could be viewed by some readers with a negative feedback due to the perceived bias of such reports. My humble submission would be to cite reports or data from reputable organizations such as the World Energy Outlook (WEO) by the International Energy Agency (IEA).	Rejected. For this particular data (refining output) BP is the most credible source. T	Vince Davidson Pacañot	University of the Philippines Diliman	Philippines
79533	12	14	13	2	Until this point it has been refered to fossil fuel CO2 or GHG emissions. Could you clarify in the text why is biomass emissions here?. If we want to mention the emission of biomass in the energy supply system, one should consider notably waste, hydropower (methane).	Rjected. Emissions are not limited to fossil fuels (see figure 6.3 bottom).	Marc Daras	CentraleSupelecAlumni	France
20893	12	33	13	33	Wind and Solar are not apparent on the Figure. Are they realy so small that they do not show up ?	Figure redesigned. However wind and solar are indeed very small.	Government of France	Ministère de la Transition écologique et solidaire	France
789	12				visiblity is very poor, ordinate is missing (6.4)	Agreed figure redesigned	Alok Dhaundiyal	Szent Istvan University	Hungary
17901	12				make clear in legend that these are ratios	Accepted- In the legend we shall add (%)	Robert Brecha	Climate Analytics	Germany
27711	12		12		Figure 6.4: presents the same data as Figure 2.20 of Chapter 2, page 54, but there are discrepancies. Consistency should be ensured.	Accepted. Important will be checked with chapt 2 to avoid repetition and ensure consistency.	Eleni Kaditi	Organization of the Petroleum Exporting Countries, OPEC	Austria
9793	13	1	13	2	please add reference	Accepted. Sentence reformulated. reference migh be added	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
8883	13	3	13	8	Having difficulty reconciling this paragraph with the figure, esp. the stats on Asia. East Asia energy sector emissions grew 6% p.a. but the orange line is flat. Could some of the colors/labels be mixed up?	Rejected. Line of Eastern Asia is blue and not orange. This is rather clear in the figure.	Seth Dunn	ServiceMax	United States of America
17197	13	3	13	3	The statement that "Increasing energy system CO2 emissions has been driven by rising emissions in China, India, and other emerging economies" is a tautology	Rejected. Not a tautology. There is still more than half of the world outside of these countries particularly all but African countries but one, Asian countries, Latin America	William Lamb	Mercator Research Institute on Global Commons and Climate Change (MCC)	Germany
30707	13	3	13	3	China's per capita CO2 emissions are larger than those of many European countries, so this statement is incorrect.	Rejected. No such statement in this page and line. "Increasing energy system CO2 emissions has been driven by rising emissions in China, India, and other"	Government of Japan	Climate Change Division - Ministry of Foreign Affairs	Japan

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
61963	13	3	13	3	Improve sentence "Increasing energy system CO2 emissions has been driven by rising emissions in China, India, and other..." to e.g. "Increase in energy system CO2 emissions has been driven by rising emissions in China, India, and other..."	Accepted. Sentence will be reformulated.	Esa Vakkilainen	LUT University, Lappeenranta	Finland
63135	13	3			Change "has" to "have"	Noted	Jennifer Sklarew	George Mason University	United States of America
74845	13	6	13	6	consider adding the word respectively after" emissions grew at annual rate of 6.0% yr-1, 5.6% yr-1, and 4.4% yr-1"..	Noted	Government of Kenya	Kenya Meteorological Service	Kenya
43539	13	7	13	7	Replace "continue" with "continued"	Noted	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy
61965	13	7	13	7	Typo: Change "the U.S. have continue to decline," to "the U.S. have continued to decline,"	Noted	Esa Vakkilainen	LUT University, Lappeenranta	Finland
4103	13	8	13	8	Please be careful about the selection of figures, because it is hard to relate Fig. 6.4 to what is said in text. For instance, Fig. 6.4 does not show CO2 per capita mentioned in text (line 3-5, page 13), while Fig. 6.3 bottom right would be sufficient to explain what is said in Line 6-8, page 13. Besides, Fig. 6.4 looks like a figure already presented in Chapter 2 and therefore redundant.	Accepted. check with chapt 2 will be carried out to ensure no repetition.	Tatsuki Ueda	National Agriculture and Food Research Organization	Japan
28497	13	9	14	13	This section reports results from energy balances without clarifying that there are very different conversion factors for different energy sources when looking at them from the perspective of the useful energy/exergy. Adding this perspective would help readers to understand that a switch towards renewable electricity and electric end-uses comes with significant inherent energy efficiency improvements and does not need to attain, in terms of absolute scale, the values of energy supply currently occupied by fossil resources, if the objective is the provision of the same services. I think a box explaining limitations of indicators like TPES and TFC in this respect would be a very good addition to this section.	Rejected. This is true. However not enough space for a box explaining primary energy and useful energy. Analysis remains valid even without this box.	Pierpaolo Cazzola	International Transport Forum	France
45471	13	9	14	13	What I miss in this section is the notion that electricity demand is stable or even declining across the OECD. This is really a trend change compared to previous periods.	Accepted. A sentence or a couple of word will be added lines 26-28	Kornelis Blok	Delft University of Technology	Netherlands
61753	13	9	13	10	"Global energy production and demand continue to grow, although the rate of increase continues to decline". First, while the rate (%) is declining, the absolute amount of primary energy consumption has grown by an average amount of roughly 10 EJ/year 2001-2019, while average growth 1965-2019 was 8 EJ/year (BP Energy Statistics 2020). This information should be included to avoid confusion. Also, this is in strong contrast with respect to the chosen illustrative pathway scenarios (Chapter 3, Fig 3.14), where the pathways show a stalling or even a decrease of the global energy use. This is a significant conflict and should be resolved in the chosen Illustrative Pathway scenarios to reflect this.	Rejected. Although we are using IEA stat (world reference for this type of data). IEA figures are correct. Consistency to be checked with chapt 3 fig 3.14	Rauli Partanen	Think Atom	Finland
64601	13	9	13	10	Clumsy and confusing sentence, change to: "Global…..grow, but at a decreasing rate."	Accepted. Formulation Might be considered	Government of Netherlands	Ministry of Economic Affairs and Climate Policy	Netherlands

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
65787	13	9	13	10	"Global energy production and demand continue to grow, although the rate of increase continues to decline". This is in stong contrast with respect to the chosen Illustrative Pathway scenarios (Chapter 3, Fig 3.14), where the pathways show a stalling or even a decrease of the global energy use. Please resolve this conflict and revise the chosen Illustrative Pathway scenarios to reflect this.	Accepted. Figures in our chapt based on IEA. Consistency will be checked with chapt 3 fig 314.	Eero Hirvijoki	Aalto University	Finland
807	13	11		30	the degradation of energy influence the rate of generation of energy from the primary sources (missing)	Rejected. Degradation of energy influence not explicit enough to be considered. This is also not considered in world energy balances.	Alok Dhaundiyal	Szent Istvan University	Hungary
9795	13	15	13	17	please add reference	Noted. At the end of the paragaph p.19 line 19 there is a cross reference.	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
74873	13	15	13	26	The description of global total primary energy grossly omits the contribution of biomass (firewood). Africa Energy outlook reports 830 million tons of oil equivalent or about 34 EJ which approximately 6% total primary energy. As it is a significant issue in the developing countries context, it will be good to present. IEA. (2019). Africa Energy Outlook 2019. www.iea.org/africa2019	Accepted. Contribution of biomass will be added	Government of Kenya	Kenya Meteorological Service	Kenya
795	13	17			remove comma after 2010 .	Noted	Alok Dhaundiyal	Szent Istvan University	Hungary
2639	13	17	13	19	Reporting renewable shares relative to total primary energy supply is highly ambigious. Do you use the total kinetic energy of the winds and the total irradiation as primary energy supply for wind power and solar PV? Otherwise, reporting TPES contributions makes highly inefficient technologies look like dominant contributors even though they might only contribute little to useful energy.	Rejected. Reporting shares of renewable energy is based on IEA energy balances. There are no regional or world energy balances and data based on useful energy	Jan Wohland	ETH Zurich	Switzerland
61755	13	17	13	19	The renewables in this context refer to solar and wind while biomass is considered separately, as indicated in Fig 6.5. Revise the text accordingly to avoid confusion.	Accepted after hydropower we shall add biofuels and waste	Rauli Partanen	Think Atom	Finland
65789	13	17	13	19	The renewables in this context likely exclude biomass as well since biomass is considered separately in Fig 6.5. Revise the text accordingly to avoid confusion.	Accepted same as above, after hydropower we shall add biofuels and waste	Eero Hirvijoki	Aalto University	Finland
79535	13	17	13	19	These lines concern the TPES by renewable. You exclude hydro, 2,5%, the remaining 2% are wind, solar, geothermal. You should mention biomass and waste which represent appr.9.3% 2018. IEA data.	Accepted. We shall add biomass & waste. We are mentioning significant changes. No need to quote all energy sources. For instance little change for hydro.	Marc Daras	CentraleSupelecAlumni	France
82305	13	17	13	17	Check if this really is all renewables, except from hydropower, OR if this only is WindSolarEtc	Noted. This is indeed all renewables (except hydro). This is the share related to TPES. The share of renewables in electricity generation is much higher	Anna Krook-Riekkola	Luleå University of Technology	Sweden
797	13	18			an annual rate	Noted- an will be added	Alok Dhaundiyal	Szent Istvan University	Hungary
63137	13	18			Need to add "an" before "annual", semicolon after "period", and comma after "however"	Noted	Jennifer Sklarew	George Mason University	United States of America
69457	13	18	13	18	It would be useful to also provide the share of the various fuels in electricity generation. Although electricity only accounts for 19% of final energy demand it is responsible for 37.5% of energy-related CO2 emissions due to the inefficiency of thermal power plants. Hydropower, solar PV and wind power count the same (in absolute energy value) in TPES and in TFC, and as they grow and replace fossil fuels in electricity generation, their share in TPES will augment faster as both numerator and denominator will change, i.e. large heat losses will disappear. In 2019 coal provied 37% of electricity globally, renewables 27% (hydro 16%, wind 5%, bio energy 2%, solar 2%), natural gas 23%, nuclear 10% and oil 3% (IEA World Energy Outlook 2020, p.344).	Noted. It will be checked whether in the text sources for electricity generation are addressed.	Cédric PHILIBERT	Institut Français des Relations Internationales	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
799	13	21			This is incorrect ' much lower growth rate' either use 'decrease in growth rate' or ' much slower…'	Noted	Alok Dhaundiyal	Szent Istvan University	Hungary
801	13	23			use definite article (before noun phrase ' the siginificant growth')	Noted	Alok Dhaundiyal	Szent Istvan University	Hungary
17327	13	23	13	23	"… significant growth of electric vehicles…" Relative growth is significant. Absolute growth is negligible in comparison with "fossil" vehicles.	Noted	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
79537	13	23			You do not mention liquid biofuels, which are more important than electric vehicles and one of the topic of the following discussion 6.4.2.6. The growth rate starting from 0 is not really meanningful	Noted. A mention or cross reference to chapt transport might be added.	Marc Daras	CentraleSupelecAlumni	France
803	13	27			increasing the use of electricity	Noted the will be added	Alok Dhaundiyal	Szent Istvan University	Hungary
45469	13	27	13	28	Box 6.1 doesn't show how much increased electricity access contributed to the growth of the share of electricity. I doubt whether it contributed at all, given the limited flows created.	Rejected. Purpose of box 61 is about access and sustainabilty. Quantitative impact of electricty access on the share of electricity stands a much lower level. No space to address such level of detail.	Kornelis Blok	Delft University of Technology	Netherlands
51343	13	28			Heat 3% of TFC? This is not all heat- e.g. coal and gas provide heat in industry.	Rejected. Figures from IEA. 3% for heat is already significant for TFC and it is very likely that this is not under-estimated by IEA.	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
51345	13	28			Suggest calling category Other where Other means sources of heat other than coal, gas, oil, biomass and waste	Rejected. We are using IEA categories. Reference included	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
69459	13	28	13	29	There would need to be a caveat here, and a reminder of the definition of the total final energy consumption (which is not found in the glossary): it's the energy that reaches the final consumer's door; not how the energy is "finally" used! Almost half (47%) of all energy needs are for domestic or industrial heat. The 3% share of heat in the TFC only represents the share of heat sold as such, e.g. in district heating systems. Without an explanation the reader might be totally confused about the real importance of heat in the energy consumption - by opposition to specific electricity consumption, light, force, movement, etc.	Accepted. Check whether TFC is included in the glossary	Cédric PHILIBERT	Institut Français des Relations Internationales	France
74875	13	29	13	29	It will be useful to define biofuels and waste in a footnote. Biofuels, biomass, bioenergy has been used interchangably in several literatures. It would be important to give specific definition to what is meant by biofuels and waste within the context.	Rejected. Biofuels and waste are defined in the glossary. These categories are those of IEA.	Government of Kenya	Kenya Meteorological Service	Kenya
37075	13	31	13	33	Fig 6.5: What is the axis? This figure needs to be explained.	Rejected. Axis (vertical and horizontal) are clear. Nevertheless figure will be redesigned	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
51347	13	31			Suggest calling Heat Other in Fig 6.5	Rejected. Categories are those of IEA. Furthermore it is important to show importance of heat	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
64603	13	31	13	34	Tiny numbers in the graphs are difficult to read and missing for some categories. Suggest to take the numbers out from the graphs and add small -but complete- tables below them.	Accepted- figures might be redesigned or numbers taken out of the figures.	Government of Netherlands	Ministry of Economic Affairs and Climate Policy	Netherlands
75023	13	31	13	32	Figure 6.5 is hard to follow, the demand and supply. They should be presented separately instead of side by side. The color coding for biofuel in demand and biofuel in supply are different. It should also be presented in regions. Whereas Coal and oil are primary energies in developed country, biomass (in this case biofuel) is dominant. It will be important to show this regional differences.	Figures will be redesigned. Howerver they will be kept side by side for space reason. Below (p 13 line 35 to page 14 line 13) explanation is provided regarding regional differences and further explanation of fig 65.	Government of Kenya	Kenya Meteorological Service	Kenya
805	13	33			the digits are overlapping in the figure 6.5 (Y label?)	Noted figure redesigned	Alok Dhaundiyal	Szent Istvan University	Hungary
809	13	36			what do you mean by 'modern fuel'? Despite using 'modern' fuel, the developed countries share in GHGs emission is way too high in the world. So, what is the point of using 'modern' fuel?	Rejected. Purpose of modern fuels is not related to GHG.	Alok Dhaundiyal	Szent Istvan University	Hungary
811	13	37	1	14	But 'fuelwood and charcoal' are mostly used in the Cambodia (95%), phillipines (90%), Pakistan (78%) , Nepal (72%) ? Correct this fallacious statement or provide the reliable source. LPG consumption is very high in residential sector in India.	Rejcted .It is clearly specified that fuelwood and charcoal are mostly used in some Asian Countries such as India. We don't quote all countries. Space constraint. LPG is not discussed in this paragraph. It is addressed in the box	Alok Dhaundiyal	Szent Istvan University	Hungary
10631	13	37	13	37	"Traditional biofuels (fuelwood and charcoal)"? According to IEA as well as general practice, the word "biofuel" is reserved for liquid or gaseous fuels, used for transportation. Since this report chooses differently, this should be indicated in the glossary, which is not the case right now.	Accepted. We shall replace biofuels with biomass and reformulate the sentence. Glossary will be checked for definition.	Philippe Waldteufel	CNRS	France
63623	13		13		On Figure 6.5, biofuels should not be used to refer to primary energy, as some conversion is required to get from the biomass to a (solid, liquid, gaseous) biofuel. Biomass is preferable.	Accepted. However the categories are those specified by IEA.	Government of Canada	Environment and Climate Change Canada	Canada
81051	14	3	14	4	This statistic appears to be incorrect. While some sub-saharan African countries do have an 80% share of their TPES from biomass, the average for the continent as a whole is much lower (e.g.: 30% according to the UNEP: the UNEP: UNEP(2017), “Atlas of Africa Energy Resources”United Nations Environment ProgrammePO Box 30552, Nairobi 00100, Kenya).	Accepted. Figure checked and amended according to IEA database which is the primary source compared with UNEP.	Aaron Barkhouse	SunPower Corporation	United States of America
813	14	5			what is OECD? Add hyphen after 'non'	Accepted	Alok Dhaundiyal	Szent Istvan University	Hungary
15239	14	5	14	6	Non-OECD Asia and China are listed in parallel here. In the original IEA report, non-OECD Asia includes China. It is suggested to change "non-OECD-Asia and China" to "non-OECD-Asia". The supporting literature is as follows: World energy balances 2020: overview (IEA,2020), Page 15, “Total final consumption has soared in non-OECD Asia since the early 2000s to account for 34% of global TFC since 2015 and a level of 3 381 Mtoe in 2018.”	Accepted. But geograhical will be checked.	Government of China	China Meteorological Administration	China
815	14	8			add comma before particularly	Noted	Alok Dhaundiyal	Szent Istvan University	Hungary
43541	14	10	14	14	This statement should be supported by at least one reference	Noted	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy
71527	14	10	14	13	In my opinion, this statement should have a citation as it is not completely neutral (e.g. regarding the use of subsidies).	Rejected No need for a reference here	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
79539	14	10			SDG 7 should be consider globally, with its targets. The title is "Goal 7. Ensure access to affordable, reliable, sustainable and modern energy for all" and the targets are the following: 7.1 By 2030, ensure universal access to affordable, reliable and modern energy services 7.2 By 2030, increase substantially the share of renewable energy in the global energy mix 7.3 By 2030, double the global rate of improvement in energy efficiency 7.a By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology 7.b By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States, and land-locked developing countries, in accordance with their respective programmes of support	Rejected. Reader can find details on the SDGS in references provided. Space constraint do not allow to include text available within UN and in many other papers	Marc Daras	CentraleSupelecAlumni	France
82535	14	10	14	12	This line addresses SDG7 and the significant current gap to achieving SDG7's universal access goal. It jumps to presume that there is agreement that this goal will be met with sustainable energy, however, which is far from a foregone conclusion. I recommend qualifying this statement to read along the following lines: "Achieving universal energy access (SDG-7) in a manner that does not further exacerbate carbon-intensive energy production and related C02 emissions in the world will require"....	Accepted. Suggested qualification will be included.	Constabile Kerry	Oxford University School of Geography	United States of America
75025	14	11	14	11	Off-grid electricity will play important role towards electricity access in Africa and in the whole report it is mentioned once in page 14 without elaborate discussion. Africa Energy outlook present very important narration about off-grid electricity supply	Accepted. A few lines will be added and references. Box for instance.	Government of Kenya	Kenya Meteorological Service	Kenya
84197	14	14	14	44	There are some drivers missing: supporting economic development and local job creation, mitigating climate change, poverty alliviation, energy justice	Other drivers are important, but the limited space is a problem. We included the drivers suggested in the first paragraph.	Lea Ranalder	REN21	France
71529	14	16	14	17	should energy demand growth be mentioned as a factor here? Many of the new coal plants are built due to growing electricity demand for example.	We included energy demand growth as a factor related to energy access, economic growth, etc.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
15087	14	18	14	22	Suggestion for amendment:At the end of this paragraph, add “However, reversing several years of progress, the number of people without access to electricity in sub-Saharan Africa is set to rise in 2020 because of the COVID-19 pandemic (IEA 2020).”。 Reason: the energy access discussed in this paragraph is up to 2017. But since the beginning of COVID-19, the progress of energy accessibility in sub Saharan Africa and Southeast Asia has regressed, and IEA expects 100 million people to return to the electricity free population due to the epidemic. Supporting literature: IEA World Energy Outlook 2020（https://www.iea.org/reports/world-energy-outlook-2020）	We added the sentence suggested.	Guoquan HU	National Climate Center of China Meteorological Adminstration	China
27713	14	18	14	22	The figures presented on energy access should be updated based on the latest available data.	We updated the figures using WEO 2020 (IEA).	Eleni Kaditi	Organization of the Petroleum Exporting Countries, OPEC	Austria

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
30709	14	18	14	22	According to IEA`s date, througout 2012-2015, 103 million people gained access to new electric power, however over 70% is derived from fossil fuel power generation. Therefore, before "Increasingly, those who gain access are doing so vie renewable sources and decentralized systems are proving cost-effective in rural areas" it should be added as "About 70% of them has got access to fossil fuel based electricity".	We added the sentence suggested.	Government of Japan	Climate Change Division - Ministry of Foreign Affairs	Japan
43853	14	18	14	22	A more updated statistics was reported in the Global Sustainable Development Report 2020, where the proportion of the population with access to basic electrcity went up from 83% in 2010 to 90% in 2018. This percent increase translates to more than 1.2 billion people having basic electricity access. Same observation was reported for those with access to clean cooking technologies and fuels, from 56% in 2010 to 63% in 2018 [7].	We updated the figures using WEO 2020 (IEA).	Vince Davidson Pacañot	University of the Philippines Diliman	Philippines
48727	14	18	14	22	The discussion on energy access here is as the date of 2017. However COVID-19 has brought new challenges. Suggest to add the following to the end of the paragraph: “However, reversing several years of progress, the number of people without access to electricity in sub-Saharan Africa is set to rise in 2020 because of the COVID-19 pandemic (IEA 2020).” Supporting document: IEA WEO2020 (https://www.iea.org/reports/world-energy-outlook-2020)	We updated the figures using WEO 2020 (IEA) and added the sentence suggested.	Qi An	Energy Research Institute, National Development and Reform Commission of China	China
63141	14	18	14	22	Continued use of diesel generators for power in remote areas should be mentioned here.	We added this idea.	Jennifer Sklarew	George Mason University	United States of America
84191	14	18	14	18	There are more recent data available on energy access. It would also be helpful to mention how many people are still lacking energy access today.	We updated the figures using WEO 2020 (IEA).	Lea Ranalder	REN21	France
85963	14	18	14	22	Suggest clarifying: "..decentralised systems are proving cost-effective way in rural areas" Does this mean to state "..decentralised systems are proving a cost-effective way to provide electricity in rural areas" ? This statement and others like it in the chapter should be contextualised with the understanding that the countries most rapidly expanding access to energy for the millions who lack it are also rapidly urbanising. In dense urban settings many 'decentralised' energy systems have limitations due to lack of open space and/or roof space.	We clarified the sentence by the suggestion.	Government of Australia	Department of Industry, Science, Energy and Resources	Australia
82537	14	19	14	20	Are decentralized systems proving cost effective in ALL rural areas? This is a big statement and needs more qualification. Also would help to identify if these decentralized systems are all powered by renewables. Sentence in reference: "decentralised systems are proving cost-effective way in rural areas (IEA 2017)."	Always it is difficult to generalize to ALL. We added references (taking into account the comment in line 182) to strengthen this point.	Constabile Kerry	Oxford University School of Geography	United States of America
817	14	20			a cost-effective.	It is done.	Alok Dhaundiyal	Szent Istvan University	Hungary
55607	14	20	14	22	What is the definition of "clean cooking"?	We added in parenthesis: "modern fuels and/or improved biomass cookstoves". Moreover, the definition of ‘clean’ products needs to be targeted and done very carefully.	Government of United States of America	U.S. Department of State	United States of America
63139	14	20			"Way" should be deleted	We changed the sentence taking into account the comments of lines 177 and 179 of this Excel. Now it does not make sense to erase "way".	Jennifer Sklarew	George Mason University	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
74877	14	20	14	20	Providing some key reference to decentralised solar PV.Harrison, K., Scott, A., & Hogarth, R. (2016). Accelerating access to electricity in Africa with off-grid solar. 26. IEA. (2019). Africa Energy Outlook 2019. www.iea.org/africa2019 Muchunku, C., Ulsrud, K., Palit, D., & Jonker-Klunne, W. (2018). Diffusion of solar PV in East Africa: What can be learned from private sector delivery models? WIREs Energy and Environment, 7(3), e282. https://doi.org/10.1002/wene.282	We added these relevant references.	Government of Kenya	Kenya Meteorological Service	Kenya
55609	14	21	14	21	Define what is meant by "clean cooking" as this is likely to be primarily LPG, which has a GHG impact, as does traditional biomass with its carbon black emissions, etc.	We added in parenthesis: "modern fuels and/or improved biomass cookstoves". Moreover, the definition of 'clean' products needs to be targeted and done very carefully.	Government of United States of America	U.S. Department of State	United States of America
80341	14	21	14	21	Access to clean cooking has been possible through LPG in a number of countries e.g. India and that will increase and decrease CO2 emissions.	We added in parenthesis: "modern fuels and/or improved biomass cookstoves". Moreover, the definition of 'clean' products needs to be targeted and done very carefully.	Subash Dhar	UNEP DTU Partnership, DTU	Denmark
43855	14	23	14	29	In a real sense, energy security cannot be dissociated with climate change (environmental sustainability) since these two are interlinked under an umbrella term called energy trilemma. Independently, energy security (as defined) enables efficient management of primary energy sources to efficiently address the demand, which basically is producing energy in a cleaner (less GHG emissions) way. A study of La Viña et al. (2018) about energy trilemma in the Philippine context can be inspected [8].	We agree that energy security cannot be dissociated with climate change, but energy security was often dissociated with climate change in the past. We mentioned this misconception in the past and its progress to nowadays conception, including the energy trilemma.	Vince Davidson Pacañot	University of the Philippines Diliman	Philippines
55611	14	23	14	29	This section has old references, and misses many key references and the link between energy security, climate, and national security.	We added some recent references and included energy trilemma.	Government of United States of America	U.S. Department of State	United States of America
79541	14	23			Energy security at local level is reliability, and which is important for electric systems. It should be mentioned here.	We added this idea	Marc Daras	CentraleSupelecAlumni	France
80119	14	23	14	29	Proper usage of the terms "security" and "safety".	We changed "human security" by "human safety".	Emil Kichev	Technical University of Sofia	Bulgaria
52153	14	25	14	28	Subjective of what are the most important challenges; this sentence is not needed.	We erased the sentence that included: "the greatest challenges".	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
85329	14	27	14	28	reference should be (Brown and Sovacool 2011)	Given that we cannot change references, "Sovacool" is inserted as a comment.	Linda Hancock	Deakin University	Australia
82539	14	28	14	29	This line references a "recent" development for climate change and energy security, but sources a document from 2013. To strengthen this point, I recommend adding a more recent citation. If possible, I recommend also referencing the recent UN Security Council meeting on climate security, which covered energy security. Sentence in refernce" More recently, the relationship between climate change and energy security has been systematically investigated (Toke and Vezirgiannidou 2013)."	We added some recent references and reorganised the paragraph.	Constabile Kerry	Oxford University School of Geography	United States of America
85331	14	29	14	29	a more recent reference than 2013 is needed for "recent" research eg review of literature in Hancock, L. and Ralph, N. A framework for assessing fossil fuel 'retrofit' hydrogen exports: Security-justice implications of Austalia's coal-generated hydrogen exports to Japan, Energy, 4 February, vol 223, 15 May 2021, 119938	We added some recent references and reorganised the paragraph.	Linda Hancock	Deakin University	Australia

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
321	14	30	14	33	Why only China is mentioned here. Air pollution is a global issue, so, either it is treated in general terms or references to other areas should also be made.	We changed the paragraph and added other references.	Sandro Fuzzi	ISAC CNR	Italy
819	14	30		33	25% PM2.5 concentration an' Confirm it from the reliable sources as it is contradictory. Did they make a target without the time frame ?	We changed the paragraph and added other references.	Alok Dhaundiyal	Szent Istvan University	Hungary
4105	14	30	14	33	The issue is not confined to China, and should be discussed more broadly; or put "for example" at the head of sentence.	We changed the paragraph and added other references.	Tatsuki Ueda	National Agriculture and Food Research Organization	Japan
15241	14	30	14	33	The "Air Pollution" is not summarized and analyzed like other factors, and it is suggested to add a general description after "air pollution”, that is “Air pollution control policies in many countries have the components about energy measures, and therefore have effects on energy development”. In addition, the air pollution control target for the Beijing-Tianjin-Hebei region of China is a 25% reduction in PM2.5 concentration from 2012 to 2017, not a reduction to 25%. It is suggested to add "reduction from 2012 to 2017" after "concentration" in line 30. It is suggested to change it to: Air Pollution. Air pollution control policies in many countries have the components about energy measures, and therefore have effects on energy development. In China, the capital region established a target of a 25% PM2.5 concentration reduction from 2012 to 2017 and released a policy that included the shutdown of all coal-fired power plants and their replacement by gas power plants in Beijing and an increase in the share of imported electricity through the extra-high voltage transmission connection (Fang et al. 2019). The supporting literature is as follows: Fang, D., B. Chen, K. Hubacek, R. Ni, L. Chen, K. Feng, and J. Lin, 2019: Clean air for some: Unintended spillover effects of regional air pollution policies. Sci. Adv., 5, eaav4707.	We changed the paragraph and added other references.	Government of China	China Meteorological Administration	China
43857	14	30	14	33	Please emphasize that air pollution is one of the most damaging direct causes of excessive GHG emissions in the atmosphere due to energy production and that it results to human health and environmental issues. The paragraph in this portion contains insufficient lead and quite lacks substance compared to previous sections.	The question for this section is about the recent changes in energy systems. Maybe the explaination suggested could be part of another section.	Vince Davidson Pacañot	University of the Philippines Diliman	Philippines
48729	14	30	14	33	Suggest to substitute the description here on Beijing to China national policies on air quality improvement, and mention policies of other major countries. Reason: air pollution is a common and important global challenge in the energy sector, and needs more representative policy examples here.	We changed the paragraph and added other references.	Qi An	Energy Research Institute, National Development and Reform Commission of China	China
50875	14	30	14	33	Is a word missing here? Suggest: "In China, the capital region established a target of a 25% PM2.5 concentration reduction and…"	We changed the paragraph and added other references.	Bianca Wernecke	South African Medical Research Council	South Africa
52155	14	30	14	33	Only mentions China; needs to be global discussion.	We changed the paragraph and added other references.	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
55613	14	30	14	30	Define what is meant by "established a target of a 25% PM2.5 concentration". As written, this does not make sense.	We changed the paragraph and added other references.	Government of United States of America	U.S. Department of State	United States of America
55615	14	30	14	33	This is a singular example vs. a compilation of literature, which is much broader and deeper than one paper (e.g., India, older U.S. debates, sector approaches, even USEPA efforts).	We changed the paragraph and added other references.	Government of United States of America	U.S. Department of State	United States of America
61199	14	30	14	33	Air Pollution. In China, the capital region established a target of a 25% PM2.5 concentration and released a policy that included the shutdown of all coal-fired power plants and their replacement by gas power plants in Beijing and an increase in the share of imported electricity through the extra-high- voltage transmission connection (Fang et al. 2019). Just take the example of the Chinese capital to illustrate that the global situation is not representative and does not match the situation in Beijing. please delete it	We changed the paragraph and added other references.	Jianguo WU	chinese research academy of environmental sciences	China
61967	14	30	14	30	Current sentence does not make sense now. Change it from "Air Pollution. In China, the capital region established a target of a 25% PM2.5 concentration and ..." to "Air Pollution. In China, the capital region established a target of a 25% PM2.5 concentration reduction and ..." to reflect original reference	We changed the paragraph and added other references.	Esa Vakkilainen	LUT University, Lappeenranta	Finland
71531	14	30	14	33	The text about air pollution does not give an introduction to the topic but describes a specific Chinese policy.	We changed the paragraph and added other references.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
84193	14	30	14	30	There is more global data available on air pollution so I suggest to expand this - and then make it clear that the driver is improving public health and well-being which can be achieved through reduced air pollution. Terminology is important here - in the end it's about people. More than 90% of urban areas were exposed to air pollution, and more than half of the population was exposed to air pollution at least 2.5 times above the guidelines established by the World Health Organization (WHO), from WHO, "9 out of 10 people worldwide breathe polluted air, but more countries are taking action", 2 May 2018, https://www.who.int/news/item/02-05-2018-9-out-of-10-people-worldwide-breathe-polluted-air-but-more-countries-are-taking-action.	We changed the paragraph and added other references.	Lea Ranalder	REN21	France
84195	14	30	14	30	On falling costs of renewables make it clear that renewables can provide an opportunity to lower operational costs and save money. In many jurisdictions renewables are now the cheapest option. See REN21 Renewables 2020 Global Status Report www.ren21.net/gsr	We added "provide an opportunity to lower operational costs and save money" to emphasize.	Lea Ranalder	REN21	France
86523	14	30	14	30	a 25% REDUCTION in PM2.5	We changed the paragraph and added other references.	raphael Slade	Imperial college	United Kingdom (of Great Britain and Northern Ireland)
821	14	34		44	Add more schemes in this part from other countries as well. Discuss about offgrid and grid connected policies. Write about NAPCC	Unfortunately, there is no more room.	Alok Dhaundiyal	Szent Istvan University	Hungary
17329	14	34	14	34	"Technology. The falling costs of solar PV, wind, and batteries is driving a major change…" Missleading statement: falling costs do not mean that particular technology is sufficiently cheap and competitive. Especially the batteries fall into the group of very expensive technologies for large-scale storage despite falling costs.	We added "provide an opportunity to lower operational costs and save money" to complement the idea.	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
33047	14	34	14	35	the same comment as comment No1.	We did not understand this comment.	Yashar Hajimolana	University of Twente	Netherlands

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
37077	14	34	14	44	Technological factor is not universally true.	We added "in some regions".	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37663	14	34	14	44	Why no reference has been made to developments that are taking place in the area of nuclear technology?	Unfortunately, there is no more room.	Ravi B Grover	Homi Bhabha National Institute	India
63143	14	34			"is" should be changed to "are"	We changed redaction.	Jennifer Sklarew	George Mason University	United States of America
63147	14	34	14	44	If Germany and China are discussed, India also should be mentioned, due to its large role in demand and plans for PV expansion.	Unfortunately, there is no more room.	Jennifer Sklarew	George Mason University	United States of America
69461	14	34	14	35	Singling out "personal transportation" is unduly restrictive. I guess this is because of the mention of batteries in that sentence. However, the falling costs of solar PV and wind is driving major changes in the entire energy system, far beyond the sole case of personal transportation, and first and foremost with the generation of electricity. But this fall in costs has the potential to support green electrification of final end uses, not only "personal" transportation but all ground transport means for people and weight, of industrial heat and space heating, of space cooling, and through the production of hydrogen on reducing process-related emissions in steel making, production of chemical, production of clean fuels for long-range aviation and maritime shipping - not to mention access and clean cooking (other areas by the way where the falling costs of batteries do matter).	We substituted "personal transportation" for "end-use sectors ".	Cédric PHILIBERT	Institut Français des Relations Internationales	France
71533	14	34	14	40	The paragraph about technologies is not very clearly formulated: Decreasing costs of PV and wind are no drivers of a change in the transport sector. It is not clear why the examples of Germany and China are given. Maybe one could state the following: While some renewable electricity plants are already installed due to revenues they get from free markets, subsidies and support schemes still play a major role. This can for example be seen in the case of China where installations decreased due to xxx. Regarding the German case, costs are high due to older installations, new ones are relatively close to market prices, so I would not mention this in the introduction on technologies and their costs.	We reorganised and changed the paragraph.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
74861	14	34	14	44	The Feed in Tariff (FiT) policy was dsigned to boost devlopment of renewable energy sources Electricity. It howevr brought about an oveload of commitments that has led to transition to Renewable Energy Auctions. The new policy may slow down, disrupt or entirely halt deployment of variable renewables	The discussion of these instruments could be part of another section.	Government of Kenya	Kenya Meteorological Service	Kenya
74879	14	34	15	20	There are described numerous couses of decline in solar PV including economy of scale, R&D etc however this is not properly distributed. The aspect cost reduction is relative to regions. In the African context is useful to note that capital investment cost still remains high. IRENA. (2016). Solar PV in Africa: Costs and Markets. 84. IRENA. (2019). Future of Solar Photovoltaic: Deployment, Investment, Technology, Grid integration and socioeconomic aspects [A Global Energy Transformation paper]. International Renewable Energy Agency. Kavlak, G., McNerney, J., & Trancik, J. E. (2018). Evaluating the causes of cost reduction in photovoltaic modules. Energy Policy, 123, 700–710. https://doi.org/10.1016/j.enpol.2018.08.015	We added "in some regions".	Government of Kenya	Kenya Meteorological Service	Kenya

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
81053	14	34	14	44	The thesis of this paragraph is a good one, but I suggest including one positive and one negative example, rather than two negative ones, to present a more balanced view of the interplay between technological advancement and climate concerns. For example, the falling cost in PV has led many jurisdictions and companies to commit to, or already achieve, 100% renewable energy goals, and countries are committing to phase-out of ICE (internal combustion engine) vehicles on timescales not thought possible even 10 years ago. These have been made possible, or even profitable, by massive cost reductions in PV, wind, and Li-ion battery storage, which were in part achieved due to progressive climate and energy policy.	We limited the space for negative examples and included the progress in batteries.	Aaron Barkhouse	SunPower Corporation	United States of America
86603	14	34	14	44	This paragraph feels quite pessimistic on the progress in clean technologies. Their is a debate around the cost of the energiewende but you are only presenting the negative case. You should add that "However, it shoudl be recognised the Energiewende has been instrumental in incentivising mass production of PV leading to impressive cost decreases in PV globally, as well as provided many co-benefits for Germany including pollution reductions, research and development, reducing import dependencies for primary energy, creating employment, and financial learning effects resulting from the high number of domestic installations (Kreuz & Musgens 2017)" - Kreuz, S., & Müsgens, F. (2017). The German Energiewende and its roll-out of renewable energies: An economic perspective. Frontiers in Energy, 11(2), 126–134. https://doi.org/10.1007/s11708-017-0467-5. - Fuentes, S., Villafafila-Robles, R., Olivella-Rosell, P., Rull-Duran, J., & Galceran-Arellano, S. (2020). Transition to a greener Power Sector: Four different scopes on energy security. In Renewable Energy Focus (Vol. 33, pp. 23–36). Elsevier Ltd. https://doi.org/10.1016/j.ref.2020.03.001 This paragraph should also mention the remarkable success of offshore wind cost declines experienced in the UK, with costs of wind energy being driven down by policy initiatives to now be one of the cheapest forms of electricity generation for the UK (Grubb & Newbery 2018) Grubb M. and D.Newbery (2018), UK Electricity Market Reform and the Energy Transition: Emerging Lessons, Energy Journal, Vol. 39, No.6, DOI: 10.5547/01956574.39.6.mgru	We limited the space for negative examples and included the progress in batteries.	Matthew Ives	University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
55617	14	35	14	35	Statement is not supported by evidence.	There are refences to other sections.	Government of United States of America	U.S. Department of State	United States of America
55619	14	35	14	44	Examples are weak. Provide broader literature and assessment of the role of technology development and climate.	Unfortunately, there is no more room.	Government of United States of America	U.S. Department of State	United States of America
73943	14	35	14	35	something is missing after "potentially"… for example "potentially used in personal transportation"	We changed redaction.	Heleno Miguel	Lawrence Berkeley National Laboratory	United States of America
4107	14	36	14	36	Insert "policy" after "climate" because of what is discussed in the following sentences.	We erased the sentence because of the lack of space and low relevance of the sentence.	Tatsuki Ueda	National Agriculture and Food Research Organization	Japan
55621	14	36	14	36	Need to add "mitigation" for this sentence to make sense: "Technological changes and climate mitigation interact with one another and reinforce one another."	We erased the sentence because of the lack of space and low relevance of the sentence.	Government of United States of America	U.S. Department of State	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
11671	14	39	14	40	While in other countries like Italy, the Energy transition is the base for the recovery and big energy players intent to base their strategies on this worthword, since according the "Renewable Energy Country Attractiveness Index" (Ernst & Young, 2020) the investments in photovoltaic can benefit from a return estimated between 6% and 10% in current market conditions.	Unfortunately, there is no more room.	CHIARA PUGNALINI	Altran Italy (Energy, Industry, Life Science division), European Commission	Italy
28399	14	39	14	41	"Because of its over cost" is unclear writing	We erased the sentence and synthesised the idea because of the lack of space.	Naud Loomans	Eindhoven University of Technology	Netherlands
79543	14	39	14	44	These lines are not related to technology, but to the economy and the cost of energy. It may go to "energy access" if it is expended to "affordability" which is a debate on the impact of price policies for climate on lower revenus household. In case of germany, the debate should be considered in reference to the energy budget of households, which is not too high comparedto other country, due to the good insulation of houses.	We changed the subtitle "Technology" for "Technology and costs"	Marc Daras	CentraleSupelecAlumni	France
82089	14	39	14	40	The connetion between the idea ending in line 39 and the idea beginning in line 40 is a bit off. As I understand it, the paragraph begins pointing out the opportunities for PV and wind energy, cost reductions and market opportunities and even points out to that decreasing costs ease the ability to implement climate policy. Then, the sentence starting in line 40: "In Germany, the transition strategy of Energiewende is under debate because of its overcost..." indicates the opposite. The las sentences of this paragraph point to energy policies that have not been successful or are questioned for their costs, (after mentioning that lower costs ease the ability for climate policy).	We reorganised ideas and changed paragraph.	Sofia Rosero Abad	University	Netherlands
84479	14	39	14	41	The literature on the transition strategy of Energiewende may be better represented and synthesized beyond the existing reference, e.g. studies in Energy Research and Social Science https://doi.org/10.1016/j.erss.2017.10.004	Unfortunately, there is no more room.	Siir KILKIS	The Scientific and Technological Research Council of Turkey	Turkey
51349	14	40			because of its overall cost, an element that could change the	We erased the sentence and synthesised the idea because of the lack of space.	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
55623	14	40	14	40	"because of its over cost": change "over" to "high"	We erased the sentence and synthesised the idea because of the lack of space.	Government of United States of America	U.S. Department of State	United States of America
63145	14	40			"over cost" is hard to understand. Suggest changing to "excessive cost" and clarifying for whom these costs are pertinent, e.g., consumers.	We erased the sentence and synthesised the idea because of the lack of space.	Jennifer Sklarew	George Mason University	United States of America
79545	14	40			"the direction for renewable energy" could be changed to "the intensity of renewable energy development policies" .	We erased the sentence and synthesised the idea because of the lack of space.	Marc Daras	CentraleSupelecAlumni	France
86525	14	40	14	40	replace " over cost" with "over budget" or "excessive cost"	We erased the sentence and synthesised the idea because of the lack of space.	raphael Slade	Imperial college	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
15243	14	41	14	44	The statement in this paragraph fails to fully reflect the latest facts. On January 20, 2021, the National Energy Administration of China released the national electricity industry statistics for 2020 which indicted that wind power and photovoltaic both have achieved significant growth, with a combined total of 120 million kW of new installations, equivalent to the sum of two years in 2018 and 2019. It is suggested to reflect this new situation. In addition, the subsidy rebate is designed not only to reduce the financial burden, but based on the facts that the cost of photovoltaic power decreases rapidly and thus grid parity is gradually achieved, which is also an inevitable measure of energy market reform. It is suggested to change it to: In China, newly installed capacity of solar PV and wind power accounts for nearly half of the world (IRENA 2020), and went much beyond than the planned targets (Jiang, 2018). There was a decline in new additions of wind and PV capacity between 2018 and 2019 due to the winding-down of renewable energy feed-in tariffs (FITs). However, there are more than half of newly installed capacity of wind and solar PV in 2020 was no subsidy, with lower price than existing coal fired power plants. Reference: Jiang, K., C. He, X. Xu, W. Jiang, P. Xiang, H. Li, and J. Liu, 2018: Transition scenarios of power generation in China under global 2 °C and 1.5 °C targets. Glob. Energy Interconnect., 1, 477–35 486, https://doi.org/10.14171/j.2096-5117.gei.2018.04.008. Notice on Matters Relevant to PV Power Generation in 2018 [Fa Gai Neng Yuan [2018] No. 823]（https://www.ndrc.gov.cn/xxgk/zcfb/tz/201806/t20180601_962736.html）	Unfortunately, there is no more room for detailing these changes.	Government of China	China Meteorological Administration	China
28499	14	41	14	42	The sentence needs updates, as China doubled new renewable capacity in 2020: https://www.reuters.com/article/us-china-energy-climatechange-idUSKBN29Q0JT.	Unfortunately, there is no more room for detailing these changes.	Pierpaolo Cazzola	International Transport Forum	France
48731	14	41	14	41	Typo - "(Leslie et al. 2016)" change to "(Leslie et al. 2016)." (period mark)	We erased the sentence and synthesised the idea because of the lack of space.	Qi An	Energy Research Institute, National Development and Reform Commission of China	China
61201	14	41	14	44	In China, there was a decline in new additions of wind and PV capacity between 2018 and 2019. The winding-down of renewable energy feed-in tariffs (FITs) is the main factor. This change in the Chinese policy is an attempt to address growing deficits in the funds used to pay for the subsidies (Hove 2020). The 2018-2019 situation alone cannot represent China's policy on the development of renewable energy. It should be deleted.	Unfortunately, there is no more room for detailing these changes.	Jianguo WU	chinese research academy of environmental sciences	China
85333	14	41	14	41	since 2016 Germany how has a national Hydrogen Strategy and so does Australia	Unfortunately, there is no more room.	Linda Hancock	Deakin University	Australia

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
48733	14	42	14	44	Suggest to change “This change in the Chinese policy is an attempt to address growing deficits in the funds used to pay for the subsidies (Hove 2020).” to “This change in the Chinese policy is an attempt to reflect the rapidly declining costs of solar PV generation, and address growing deficits in the funds used to pay for the subsidies.” Reason: the objective of the retreat of China's renewable subsidies is not only on addressing deficits, more importantly, it is an act in response to the reducing costs of PV and parity on the grid, as well as a step for energy market reform. Supporting document: NEA policy [2018] 823 (https://www.ndrc.gov.cn/xxgk/zcfb/tz/201806/t20180601_962736.html)	We erased the sentence and synthesised the idea because of the lack of space.	Qi An	Energy Research Institute, National Development and Reform Commission of China	China
53723	14	42	14	42	The original text pointed out that the decrease in new installed capacity of wind power and solar energy in China between 2018 and 2019 was due to China's reduction of subsidies for renewable energy, which led to a reduction in the feed-in tariff of renewable energy. This explanation is not comprehensive. The decrease in new installed capacity between 2018 and 2019 is partially due to the cancellation of subsidies on the one hand, and on the other hand, it is also a response to the problem of insufficient power grid absorption and wind and solar abandonment issues.	We erased the sentence and synthesised the idea because of the lack of space.	ZHENG XINZHU	China University of Petroleum (Beijing)	China
79547	14	42	14	44	For China, do you want to say that the FIT is a subsidy? FIT have been installed to allow a deploiement of non competitive technology with an external benefit so that the market development induce cost reduction. At present, the price of solar PV is competitive, as wind onshore, and the removal of FIT is normal process. This sentence should be better discussed in a § on economic instruments for climate policies.	We erased the sentence and synthesised the idea because of the lack of space.	Marc Daras	CentraleSupelecAlumni	France
33049	15	3	15	4	I would say beside electricity, access to heating (e.g. space heating and warm water) is also an essential societal priority, specially in cold areas and during winter season.	Rejected. See diagram box 61 fig 1 for end uses. No space to elaborate . Furthermore, Electricity and clean cooking fuels can be used for heating	Yashar Hajimolana	University of Twente	Netherlands
823	15	5			What is SDG7? Abbrevation must be mentioned somewhere as TFC or other abberivations are provided in-text,	Noted- all acronyms will be spelled out for all chapters	Alok Dhaundiyal	Szent Istvan University	Hungary
79549	15	5			see comment on SDG 7 above.	Noted- all acronyms will be spelled out for all chapters	Marc Daras	CentraleSupelecAlumni	France
33051	15	8	15	8	I would say the "the ultimate goal is universal access to the clean energy such as electricity, heat and fuels for heating and cooling of the built environment and industry, power and water consumption and transportation.	Rejected no space, Furthermore fig 1 61 provides end uses	Yashar Hajimolana	University of Twente	Netherlands
37665	15	8	15	9	Figure 1 refers to household heating. It should refer to household space conditioning as air-conditioning load in countries in tropics is increasing rapidly.	No space to detail further. Space conditioning is included under Electricity index .	Ravi B Grover	Homi Bhabha National Institute	India
52157	15	8	15	8		There is no comment	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
78243	15	8	15	9	Omission - House Hold Energy requirements omit the central air-conditioning in several countries.	Rejected. Space conditioning is included under Electricity index .Figure does not detail all end uses.	Reetesh Chaurasia	Department of Atomic Energy, Government of India	India

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
28403	15	11	15	19	The tone in the text of the first sections (Executive summary, 6.1-6.3) is fairly negative. Of course the energy transition is still not on the required pace to achieve the climate goals, making the alarming tone understandable. However the positive trends should also be celebrated. In general I think it is relevant to think on which tone this report should have, now it is mainly alarming. It could give a more balanced overview if some of the positive change going on is highlighted more. This specific sentence clearly underlines the point in how facts can be stated in different ways. First as an example a recent report bij (BloombergNEF 2021) "Sub-Saharan Africa's electricity access rate is at its highest-ever level, but much more is needed" and IPCC "Despite progress in some countries such as India, Bangladesh and Kenya, 860 million people were 12 without access to electricity in 2018, compared with 1.2 billion in 2010. Source: BloombergNEF (2021). BNEF Executive Factbook. https://assets.bbhub.io/professional/sites/24/BNEF-2021-Executive-Factbook.pdf	Noted. The views expressed in the report remain fair. Purpose is to highlight the gap in access rather than provide a broad statement non useful for policy makers	Naud Loomans	Eindhoven University of Technology	Netherlands
37505	15	11	15	12	Important to clarify that 860 million people gobally do not have access to electricity (otherwise it gives the impression that these 860 million people reside in India, Bangladesh and Kenya!)	Accepted. we shall add worldwide	Government of India	Ministry of Environment, Forests and Climate Change	India
61099	15	11	15	12	"Despite progress in some countries such as India, Bangladesh and Kenya, 860 million people were without access to electricity in 2018, compared with 1.2 billion in 2010." This sentence gives impression as if 860 million people are without electricity access in these three countries, please check.	Accepted same as above.	LOKESH CHANDRA DUBE	TERI School of Advanced Studies	India
80139	15	11	15	25	In addition to IRENA and the other organizations cited as sources by this passage, the UN Foundation's Clean Cooking Alliance may also be a helpful resource potentially, especially in regard to more niche emerging clean cooking technologies	Noted	Robin Happel	Yale Center for Environmental Law & Policy	United States of America
43543	15	14	15	14	Insert space after ")."	NOted	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy
61969	15	14	15	14	Typo: change "Bank 2020).Around" to "Bank 2020). Around"	Noted	Esa Vakkilainen	LUT University, Lappeenranta	Finland
825	15	16		17	Are anthropegenic acvitvities more responsible than the industrial emission? 30% China, 15% USA, 9% EU, 7% India (fossil fuel).So, a huge chunk in Asia and America.	Rejecte. Comment not related to page and lines.	Alok Dhaundiyal	Szent Istvan University	Hungary
827	15	20			on-grid, least-cost options	Noted	Alok Dhaundiyal	Szent Istvan University	Hungary

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
12195	15	20	15	21	Renewables are not the least cost option for access to electricity. The report on “Projected Costs of Electricity Generation 2020” recently published by the International Energy Agency and OECD Nuclear Energy Agency, proved that generation costs from new nuclear power are competitive compared with other low-carbon options, particularly when the system costs of higher shares of intermittent generation are included. As the report mentions, electricity produced from nuclear long-term operation (LTO) is highly competitive and remains not only the least cost option for low-carbon generation - when compared to building new power plants - but for all power generation across the board. Also, advances in nuclear such as SMRs have the benefits of flexibility and scalability being able to supply baseload clea and reliable energy to deprived areas.	Noted. We shall add very likely and also a reference.	Lavinia Rizea	SN Nuclearelectrica SA	Romania
52159	15	20	15	21	Sentence needs reference; currently too dispositive and should be qualified.	Accepted. reference will be added and qualification included.	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
76389	15	20	15	25	This para does not provide a balanced view of clean low cost energy provision to developing countries. The nations of Bangladesh, India and Pakistan are all deploying new nuclear energy plants to provide reliable low carbon low cost energy that is free from the vaguries of the weather especially in localities prone to monsoons. Oher low income nations such as Egypt and Turkey are building or about to build new nuclear plants and the Phillipines is re-engaging with the technology.	Rejected. Most people without electricty access are very far from the grid. Decentralised options are very like the least -cost option for this category of population as demonstrated by many studies.	Robert Parker	Nuclear for Climate Australia	Australia
77205	15	20	15	21	The sentence "Research indicates that decentralised renewables and on grid renewables are least cost options to provide universal access to electricity by 2030" is highly questionable, as other researches indicate different conclusions. Also, transition from coal or kerosene to natural gas could just be considered a palliative temporary solution before a final shift to (e.g.) low-carbon electricity.	Sentence will be qualified. references will be added	Giacomo Grasso	ENEA	Italy
84283	15	20	15	21	The least cost aspect of decentralized renewables for energy access should be discussed in relation with LOLE issue (Loss Of Load Expectation): In case of LOLE of the same order of magnitude of developed countries (3h/year in EU), the cost of renewable is significantly increased by back-up or storage or inertia or ICT-control capabilities; or extra capacities...	Noted	Vincent MAZAURIC	Schneider Electric	France
69463	15	21	15	21	Please add electric cooking, notably electric pressure cookers, in the list of of the key "measures" ("tools", "devices or fuels" would be a more appropriate wording). Electric cooktops, kettles and rice cookers are significantly more efficient than LPG and natural gas stoves. Electric pressure cookers bring this efficacy to a much higher level by sharply reducing cooking times thanks to pressure, and reducing heat losses thanks to insulation. Some developing countries have begun moving from LPG to electric cooking to cut expensive public subsidies while preventing people to go down the fuel ladden back to biomass cookstoves. Improved cookstoves, despite decades of diffusion, have a very mixed record. A reference to this would be the Esmap, MECS and World Bank Group, 2020, Cooking with Electricity, A Cost Perspective	Accepted. E-cooking will be considered and suggested reference included	Cédric PHILIBERT	Institut Français des Relations Internationales	France
71535	15	24	15	25	The use of a quotation from 2012 with regards to technology costs of PV and wind seems extremely outdated as costs have been reduced substantially since this time.	Accepted- Recent refrences will be included	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
63149	15	26			Should this read "SDGs" or "SDG 7"?	Noted. SDG7	Jennifer Sklarew	George Mason University	United States of America
74183	15	26	15	28	First sentence should be modified to include nuclear power.	Rejected. Universal access and linkages with SDGs will mainly involved decentralised energy options.	Jeffrey Merrifield	Pillsbury Law Firm	United States of America
74781	15	26	15	28	The sentence 'Substantial progress towards SDG, even without reaching universal access by 2030, will have an important impact on energy systems, particularly power systems with the deployment of renewable energy, natural gas infrastructure, LPG, and biomass supply chains (high confidence)' may have to be revised. Few suggestions; (1). the sentence can be rearranged (2). "even without reaching universal access by 2030" may be enclosed in bracket, and (3). the long single sentence can be broken down into two more meaningful sentences.	Noted. Breaking down sentence will be considered	Semilore Abikoye	Department of Chemical Engineering, University of Cape Town	South Africa
77207	15	27	15	28	Reference to renewable energy, rather than low-carbon energy, is limitative and should be avoided in general.	Noted.	Giacomo Grasso	ENEA	Italy
69465	15	30	15	32	The reference to a paper published in 2013 relative to energy poverty seems somewhat outdated, as in the ~ten years since they get data and today, the cost of PV has been roughly divided by 10, opening entirely new avenues for providing access and clean cooking without generating additional GHG emissions.	Accepted. lines 28- to 33 will be replaced by input with recent reference mainly from IEA	Cédric PHILIBERT	Institut Français des Relations Internationales	France
78463	15	30	15	32	"Chakravarty & Tavoni (2013) calculated that ... the necessary infrastructure would generate around 44-183 GtCO2 during the century". This publication [not listed on p. 139, its DOI is: http://dx.doi.org/10.1016/j.eneco.2013.09.022] is outdated because it assumed the current global average energy mix, while the deployment of PV and wind generates significantly less CO2. Please, do not use outdated publications, better write nothing about the CO2 emissions of the necessary infrastructure, they are nearly negligible anyway. Better focus your text on what really matters.	Accepted- Same as above . lines 28- to 33 will be replaced by input with recent reference mainly from IEA	Pietro Altermatt	Trinasolar, Changzhou, China	Germany
60135	15	32	15	32	remove brackets while quoting reference	Noted	Umasankari Kannan	Bhabha Atomic Research Centre	India
61971	15	32	15	32	Typo: change "0.13 ° C." to "0.13 °C."	Noted	Esa Vakkilainen	LUT University, Lappeenranta	Finland
28501	16	4	19	29	This whole sections seems a triumph for a conservative take on how the energy system is evolving. Impressively, this section does not include any consideration on investment shits. There are many sources that can help improve the tone and accuracy of this section, when it comes to forward-looking considerations. In particular, see https://www.reuters.com/article/us-global-energy-funds-idUSKBN27Y1YD , https://www.iea.org/reports/world-energy-investment-2020/key-findings , https://www.irena.org/newsroom/pressreleases/2020/Jun/Renewables-Increasingly-Beat-Even-Cheapest-Coal-Competitors-on-Cost , https://carbontracker.org/reports/how-to-waste-over-half-a-trillion-dollars/ , https://www.bloomberg.com/graphics/climate-change-data-green/investment.html , https://about.bnef.com/new-energy-outlook/	Noted. This section focuses on recent trend of coal phaseout, added one sentence on investment shift.	Pierpaolo Cazzola	International Transport Forum	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
29401	16	4	19	3	The material in the text and the box is repetitive but at other times contradicting each other, and thus confusing. In the 2nd and 3rd paragaphs in Section 6.3.4 (page 16) they give the impression that China, e.g., is replacing coal power plants with higher efficiency ones--please provide qaantity?	Noted. Shortened and re-organized the box.	Singfoong Cheah	Independent consultant, formerly more than 10 years with the National Renewable Energy Laboratory, USA	United States of America
82541	16	4	18	3	The coal phase out section does not mention the need for readily available, affordable scalable, alternative built environment materials that do not rely on coal for production. Without such alternatives, coal phase out plans will falter. As urbanization and infrastructure requirements grow over the next 30 years, particularly in Asia and sub-Saharan Africa, building materials that require coking coal for production (e.g. steel) will be in significant demand. (This point deserves attention in both the energy and the building chapters).	Rejected. This section focuses on recent trend instead of phaseout strategies.	Constabile Kerry	Oxford University School of Geography	United States of America
64127	16	5	16	6	The statement "Global coal consumption declined from its peak in 2013 through 2016 increased from 2017 to 2018 and dropped again in 2019 (Figure 6.5)" is not demonstrated by Figure 6.5. The coal curve in the figure is almost flat at 161 EJ from 2013 to 2018 and data of 2019 has not been plotted in the figure.	Accepted and revised. Added citation from IEA.	Ghulam Rasul Athar	Pakistan Atomic Energy Commission	Pakistan
64605	16	5	16	6	The relatively small changes up and down since 2013 are not visible in Figure 6.5, and are probably not very significant. Why not simply say that coal use increased slightly until around 2013 to remain more or less stable after that.	Accepted and revised. Added citation from IEA.	Government of Netherlands	Ministry of Economic Affairs and Climate Policy	Netherlands
84285	16	5	16	42	Accoding to WEO 2018, the global change in electricity energy mix observed during 2000-17 is the replacement of nuclear capacities by renewables, letting the share of fossil globally unchanged (and actually the emission on the rise). A more detailed analysis shows the replacement of coal by gas within the fossil generation.	Rejected. Regional trends vary.	Vincent MAZAURIC	Schneider Electric	France
829	16	6			Several	Editorial.	Alok Dhaundiyal	Szent Istvan University	Hungary
61973	16	7	16	7	Typo: change "U.S," to "U.S.,"	Accepted and revised.	Esa Vakkilainen	LUT University, Lappeenranta	Finland
831	16	8		9	Is it correct way of writing 'Many of these regions have implemented moratoriums on new coal power generation without (CCUS)' ?	Accepted and revised.	Alok Dhaundiyal	Szent Istvan University	Hungary
43859	16	8	16	9	Answer this question: "Why did they impose moratorium on greenfield (or new) coal investments?". Energy-intensive countries, such as developed countries, reduce their GHG emissions through imposition of moratoriums as part of their climate commitments to the Paris Agreement and other emissions reduction and avoidance agreements in lieu of energy transition. However, the fallback of these moratoriums is that they really cannot dramatically reduce the emissions from coal plants instantly because the moratoriums only cover new coal investments. Operational power plants, who have a lifespan of 20-30 years, are not covered. Also note that some developing countries, like the Philippines, have already enforced a coal moratorium since October 2020.	Rejected. This section focuses on recent trend of coal.	Vince Davidson Pacañot	University of the Philippines Diliman	Philippines
64311	16	8	16	9	Does moratorium mean that there is a legal framework? It is true that no new construction is taking place, but a careful explanation in relation to the regulations is needed.	Accepted and revised.	Takashi Hongo	Mitsui & Co. Global Strategic Studies Institute	Japan
833	16	9		10	Incorrect statement 'In contrast, coal use continues to increase in other regions, especially in major developing Asian economies' Look at the current energy policies of the major asian countries, India, China, Russia. Read about 'ESCerts'	Rejected. This is a statement of recent coal consumption trend, not policies.	Alok Dhaundiyal	Szent Istvan University	Hungary

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
28401	16	9	16	9	(CCUS) should be CC(U)S	Accepted and revised.	Naud Loomans	Eindhoven University of Technology	Netherlands
43545	16	9	16	9	Remove brackets around CCUS	Accepted and revised.	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy
61203	16	10	16	11	Coal-fired power generation capacity growth in China, India, and other countries, such as Indonesia, Vietnam, Turkey, and Bangladesh, has offset the reduction in the OECD. This is not in line with China's situation, China's coal-fired power generation capacity is declining	Rejected, incorrect.	Jianguo WU	chinese research academy of environmental sciences	China
78465	16	11	16	12	"Coal-fired power generation capacity growth in China, India, and other countries, such as Indonesia, Vietnam, Turkey, and Bangladesh, has offset the reduction in the OECD (Jakob et al. 2020)." better replace this sentencew with: "Coal-fired power generation capacity growth in China and India has offset the reduction in the OECD (Jakob et al. 2020)" becasue the other mentioned countries are rather insignificant.	Noted and revised to "other South and Southeast Asia".	Pietro Altermatt	Trinasolar, Changzhou, China	Germany
837	16	12			remove comma after Bangladesh	Rejected.	Alok Dhaundiyal	Szent Istvan University	Hungary
85335	16	12	16	12	It should be added that those countries like Australia not just continuing use of coal, new mines and exports should be retiring coal and taking responsibility for global emissions	Accepted and revised. Separate large coal producing and consuming countries.	Linda Hancock	Deakin University	Australia
835	16	13		15	"rapidly declining costs of renewables, and inexpensive shale gas especially in the U.S." Life cycle assessement required . Fracking and shale gas extraction is lambasted in itself the US, so it is just like to choose between 'the hammer and the anvil. Show the other side of this policy as well. What about land contamination?	Rejected. Here is a statement of recent observations instead of a judgement of energy transition strategy.	Alok Dhaundiyal	Szent Istvan University	Hungary
37495	16	13	16	14	"Second, reductions in coal use have often been driven by non-climate factors, most notably environmental regulations"- Factors also includes Energy Security	Noted, but energy security has been a factor of increasing coal use; discussed in the fourth point.	Government of India	Ministry of Environment, Forests and Climate Change	India
77209	16	13	16	15	Rapidly decreasing costs of renewables is listed as a driving factor for reduction in coal use, but the case of Germany goes exactly in the opposite direction properly to contrast the increased energy cost due to the larger penetration of renewables. This case should be included in the discussion, or the cause-effect connection above removed or rephrased.	Rejected. Due to word limit, discuss general trend, no space to fill in specific cases.	Giacomo Grasso	ENEA	Italy

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
37667	16	14	16	14	Here reference has been made to declining costs of renewables. This phrase that is "declining costs of renewables" is doing maximum damage to the cause of decarbonisation. This has given rise to expectation in the mind of public that electricity tariff will declne with increasing penetration of renewables. All professionals know that this is not the case. When all is accounted for, renewabls are expensive. For the situation in India, please see Economic Survey, Vol II, 2017, published by Ministry of Finance. It uses the concept of social cost of energy generation to denote sum of all the costs, and besides the private costs of generation, includes social costs of carbon, health costs, cost of intermittency, the opportunity cost of land, the stranded assets, and cost of Government incentives. The survey estimates that social costs of renewables in 2017 was around 3 times that of coal at Rs 11 per kW-hr (page 127). The Survey strikes a cautionary note, "while investments in renewable energy is crucial for India to meet its climate change goals, such investments be made at a calibrated pace looking into the total cost accrued to the society" (Page 128). The goal of net zero cannot be reached on the basis of false narratives (Please refer to Grover, R. B. 2020, "An examination of the narratives about the electricity sector", Current Science, 119(12): 1910-1918.)	Rejected. Here the statement is not about comparing the costs between coal and renewables, which has been assessed by many literature as well. Here is an observation of recent trends that renewable energy has been growing strongly with rapidly declining costs, and the growth in renewable has replaced coal in power generation.	Ravi B Grover	Homi Bhabha National Institute	India
839	16	15		17	coal-fired power stations, the coal-fired industry	Accepted and revised.	Alok Dhaundiyal	Szent Istvan University	Hungary
79551	16	15			"inexpensive shale gas especially in the US" should read "very competitive non-conventional gas in the US" to reflect the specific US situation and the origin of gas (tight oil for some part)	Noted and revised. Lower gas prices are observed globally	Marc Daras	CentraleSupelecAlumni	France
841	16	17		19	No time frame 'air quality concerns in China have led to a shutdown of coal fired industry and' They have target and it is not yet closed (they stated that they would do so by 2020). 'Fossil-fuel power plants, of which more than 90 per cent are coal-fired, supplied 70 per cent of China's electricity in first 10 months of this year' True story. Use independent source	Noted and updated the texts.	Alok Dhaundiyal	Szent Istvan University	Hungary
15089	16	20	16	22	In recent years, China has focused on the development of clean energy such as natural gas and renewable energy, and its consumption increment has increased rapidly from 19.89 million tons of standard coal in 2011 to 91.52 million tons of standard coal in 2018. Especially in 2015 and 2016, the consumption increment of clean energy in China was greater than that of primary energy, and there was room for clean energy consumption to supplement the consumption increment of high-carbon fossil energy to reduce (Refer to China energy statistical yearbook over the years). It is suggested that this feature should be reflected in the paper.	Noted. Already mentioned old coal is replaced by new coal and renewable. Also, this section focuses on coal trend, and RE is discussed in the next section.	Guoquan HU	National Climate Center of China Meteorological Adminstration	China
61205	16	22	16	25	Although air quality concerns have pushed out the old, dirty, inefficient coal plants in China, larger and more efficient coal plants are being added. Replacing coal with gas or new coal facilities is inconsistent with limiting warming to 1.5ºC or 2ºC (Pfeiffer et al . 2016; Pfeiffer et al. 2018; Smith et al. 2019; Tong et al. 2019). This is not in line with the development of China, especially old, dirty, inefficient coal plants in China, please delete	Rejected. Unclear which part of the texts the reviewer does not agree with.	Jianguo WU	chinese research academy of environmental sciences	China
63625	16	24	16	25	Is this also accurate in low-income developing countries or countries where there are little competitive renewable alternatives? (E.g. Mongolia). It would be good to highliht if there are nuances, especially when it comes to replacing coal plants with Combined cycle natural gas power plants.	Rejected. Due to word limit, discuss general trend, no space to discuss specific cases.	Government of Canada	Environment and Climate Change Canada	Canada
78159	16	24	16	25	This is an important fact, please consider elevating to the executive summary.	Noted.	Charlotte Plinke	Climate Analytics	Germany

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
10059	16	26		34	Countries with abundant coal reserves will tend to still use coal as it is their local energy source. With the necessity to have low-cost, stable, baseload providing power plants (something that still can't be provided by variable renewable energy), coal use is still locked-in thus the idea that it will be stranded assets seems far-fetched for those countries. Are there any studies that estimates what - when – how variable renewable energy can serve baseload in competitive price with coal power plants?	Noted and clarified. Stranded assets are discussed in the context of meeting global climate goals.	Government of Indonesia	Ministry of Environment and Forestry	Indonesia
43861	16	26	16	27	In fact, some countries are keen on pursuing "clean coal investments". In the case of the ASEAN countries, the ASEAN Center for Energy had signed a 3-year Memorandum of Understanding with the World Coal Association to promote clean coal technology across the ASEAN member states. Check the article in reference link [9].	Rejected. Unclear what "clean coal investments" means.	Vince Davidson Pacañot	University of the Philippines Diliman	Philippines
85965	16	26	16	28	'Major coal consuming countries are still far from phasing out coal. China, the U.S., Australia and South Africa continue to extract and use substantial amounts of coal.' Recommend Australia is deleted from the text. According to the IEA 2020 World energy balances, Australia's coal consumption (42,936 ktoe) in 2018 is an order of magnitude lower than the other countries reported in this text including China (1, 979,524 Ktoe), the US (320, 649 ktoe) and South Africa (98,284ktoe). The text overstates where Australia sits in terms of global coal consumption and could mislead readers.	Accepted and revised.	Government of Australia	Department of Industry, Science, Energy and Resources	Australia
61207	16	27	16	30	China, the US, Australia and South Africa continue to extract and use substantial amounts of coal. In most developing countries with abundant coal reserves, coal use has been increasing to support energy security and because it is perceived to have lower costs than alternatives (Steckel et al. 2015). This single document does not fit the current situation in China, please delete	Rejected. Unclear which part of the texts the reviewer does not agree with.	Jianguo WU	chinese research academy of environmental sciences	China
63151	16	27			India should be included here.	Accepted and revised.	Jennifer Sklarew	George Mason University	United States of America
77211	16	28	16	30	The phrasing "coal use has been increasing [...] because it is perceived to have lower costs than alternatives" is partisan: it is a matter of facts that coal energy is one of the cheapest (when no carbon tax is considered).	Rejected.	Giacomo Grasso	ENEA	Italy
10061	16	35		42	Are there any lessons learned or recommendation of "just transition" from coal to cleaner energy industry?	Rejected. Due to space limit, cannot dive into the details of just transition. section 6.3.7 discusses more on the tranisition strategies.	Government of Indonesia	Ministry of Environment and Forestry	Indonesia
52185	16	36	16	36	"Occupation" is the wrong word in this context.	Unclear. Didn't use occupation.	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
843	16	38			a net increase	Accepted and revised.	Alok Dhaundiyal	Szent Istvan University	Hungary
52161	16	40	16	40	"Just transition" needs to be defined.	Rejected. Due to space limit, cannot dive into the details of just transition. section 6.3.7 discusses more on the tranisition strategies.	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
29403	16	43	19	3	Normally, a boxed content should highlight a certain part of the writing, giving it extra attention. The box in this section is big, it does not serve the purpose. Suggests putting different regions in different boxes,.	Noted and shortened the texts.	Singfoong Cheah	Independent consultant, formerly more than 10 years with the National Renewable Energy Laboratory, USA	United States of America
29405	16	43	19	3	To benefit decision makers, consider separate out (1) status (include how much coal plant phase out is necessary with table or figure), (2) clear writing of challenges by regions, (3) recommendations of how to address the challenge. As it is, it is confusing reading without some suggested paths or solutions.	Noted and shortened the texts. Transition strategies are discussed in section 6.3.7	Singfoong Cheah	Independent consultant, formerly more than 10 years with the National Renewable Energy Laboratory, USA	United States of America
47039	16	43	19	3	I think Southeast Asia must also be featured in this box, as coal phaseout is a significant challenge in this region, which is projected for significant economic growth in the following decades yet have coal plants in the pipeline.	Noted and changed the China and India paragraph to Asia.	John Leo Algo	Living Laudato Si' Philippines	Philippines
69473	16	43	19	3	The Box 6.2 could elaborate somewhat on the case of Japan, which intends to reduce the emissions of its coal plants by co-combustion of low-carbon ammonia (green or blue) imported. This was part of the Basic Hydrogen Strategy adopted by the Government of Japan in December 2017, and has been picked up notably by the largest utility, JERA, just a week before the Prime Minister announced Japan's Net Zero Emissions by 2050 ambition. See https://www.jera.co.jp/english/corporate/zeroemission	Noted and changed the China and India paragraph to Asia.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
69475	16	43	19	3	The Box 6.2 could also mention the reconversions of some coal plants in biomass plants, such as in the UK and France.	Noted. Added one sentence summarising different strategies of phasing out coal plants.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
69477	16	43	19	3	The box 6.2 could discuss the possible role of former coal plants in high share of variable renewable power systems, such as their conversioin into synchonous condensers providing system inertia, increased short-term overload capability, low-voltage ride through, fast response, additional short-circuit strength, as Denmark in particular has done. See e.g. https://www.entsoe.eu/Technopedia/techsheets/synchronous-condenser	Noted. Added one sentence summarising different strategies of phasing out coal plants.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
845	17	1			the retirement	Editorial	Alok Dhaundiyal	Szent Istvan University	Hungary
72561	17	1	17	1	Extremly low resolution of BOX 6.2.	Accepted and updated.	Yun Hang	Emory University	United States of America
9801	17	2	17	4	please add reference	Unclear.	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
63627	17	2	17	2	Would that infer that there shouldn’t be any operational coal power plants past 2041, across all regions? Suggest highlighting that finding more clearly.	Noted.	Government of Canada	Environment and Climate Change Canada	Canada
847	17	5			Is it necessary to write 'a number of'?	Editorial.	Alok Dhaundiyal	Szent Istvan University	Hungary
9565	17	5	17	5	modify "year" by "years"	Accepted and revised.	Jaume Gasia	Jose Antonio Romero Polo SA	Spain

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
20079	17	5	17	8	see also: - Antosiewicz, M., Nikas, A., Szpor, A., Witajewski-Baltvilks, J., & Doukas, H. (2020). Pathways for the transition of the Polish power sector and associated risks. Environmental Innovation and Societal Transitions, 35, 271-291. - Nikas, A., Stavrakas, V., Arsenopoulos, A., Doukas, H., Antosiewicz, M., Witajewski-Baltvilks, J., & Flamos, A. (2018). Barriers to and consequences of a solar-based energy transition in Greece. Environmental Innovation and Societal Transitions, 35, 383-399. -Nikas, A., Neofytou, H., Karamaneas, A., Koasidis, K., & Psarras, J. (2020). Sustainable and socially just transition to a post-lignite era in Greece: a multi-level perspective. Energy Sources, Part B: Economics, Planning, and Policy, 15(10-12), 513-544.	Noted. Thank you for the refereces.	Haris Doukas	National Technical University of Athens, Greece	Greece
9567	17	8	17	8	delete "a" before "(Jakob"	Accepted and revised.	Jaume Gasia	Jose Antonio Romero Polo SA	Spain
48735	17	8	17	8	Typo - “institutional lock-in, a” change to “institutional lock-in”,	Accepted and revised.	Qi An	Energy Research Institute, National Development and Reform Commission of China	China
849	17	10			better forecasting	Accepted and revised.	Alok Dhaundiyal	Szent Istvan University	Hungary
49755	17	11	17	11	“ but imminent” may be deleted. In the same line ‘ will be’ should be replaced by ‘may be’	Noted and revised.	PINAKI SARKAR	CSIR-CIMFR, Dhanbad	India
851	17	13		14	Figure visibility is very poor.	Accepted and updated.	Alok Dhaundiyal	Szent Istvan University	Hungary
2641	17	13	17	20	The Figure resolution is too low to meaningfully evaluate it.	Accepted and updated.	Jan Wohland	ETH Zurich	Switzerland
4171	17	13	17	13	Resolution is very poor on Charts a to d. Labeling is almost ineligible.	Accepted and updated.	Neil M. Mulchan	Adventure Physics, LLC	United States of America
9569	17	13	17	13	bad image quality	Accepted and updated.	Jaume Gasia	Jose Antonio Romero Polo SA	Spain
28939	17	13	17	14	Figure hardly readible.Please improve quality	Accepted and updated.	Fabian Heymann	INESC TEC	Switzerland
64607	17	13	17	20	Box 6.2, Figure 1: Panels (c) and (d) suggest there exist just one coal power pathway to reach a 1.5C (blue) or 2C (green) target. This is misleading as it is based on just one reference. If the full set of published 1.5/2C scenario studies had been drawn upon, wide fans would have resulted instead of single lines, without losing the key message that current and planned coal power capacitiy conflicts with the Paris commitments.	The value of this figure is to show the implication of Paris climate goals to individual coal plants' lifetime, by comparing the bottom-up analysis with the top-down IAM 1.5c and 2c pathways. We cannot make changes to the original chart from the literature, but the study includes a comparison chart of the 1.5c and 2c pathways with the IPCC 1.5C database. Added a note in the figure legend.	Government of Netherlands	Ministry of Economic Affairs and Climate Policy	Netherlands
79775	17	13	17	14	The figure is not clear even in the highest possible zoom in Acrobat reader DC. The figure is not clear and visible	Accepted and updated.	Constantinos Psomopoulos	University of West Attica, Department of Electrical and Electronics Engineering	Greece

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
85967	17	13	17	20	Comments on Figure 6.2: 1) Please clarify subplot (a): Does the subplot show retirement ages for limiting warming to 1.5 degrees Celsius or does it show retirement ages for limiting warming to 2 degrees Celsius? The figure caption suggests that it shows both. Please check this.. 2) See subplot (b). Consider changing the x-axis unit to age. The unit "vintage year" requires the reader to calculate the age of the power plant by subtracting the vintage year from 2021. 3) Consider using data or graphics from Tong et al. (2019) [cited in this chapter] that also shows planned coal-fired infrastructure. Tong, D., Zhang, Q., Zheng, Y., Caldeira, K., Shearer, C., Hong, C., Qin, Y. and Davis, S.J., 2019. Committed emissions from existing energy infrastructure jeopardize 1.5 C climate target. Nature, 572(7769), pp.373-377.	Plot (a) shows historical retirement age distribution. Plot (b) we cannot make changes to the original chart from the literature.	Government of Australia	Department of Industry, Science, Energy and Resources	Australia
78583	17	14	17	14	poor quality of figures shall be avoided. The information cannot be read, thus is worthless	Accepted and updated.	Christian Breyer	LUT University	Finland
49757	17	21	17	21	'today' may be replaced by ' as per current scenario'	Editorial	PINAKI SARKAR	CSIR-CIMFR, Dhanbad	India
855	17	22		24	correct the sentence 'hese initial efforts have not reached the 5-7% in global annual reduction required to limit warming to 1.5°C target'	Revised.	Alok Dhaundiyal	Szent Istvan University	Hungary
17479	17	22	17	22	reduction of CO2 or GHG. Please clarify.	Revised the sentence and removed the detailed numbers.	Alaa Al Khourdajie	IPCC	United Kingdom (of Great Britain and Northern Ireland)
853	17	24			a global	Editorial.	Alok Dhaundiyal	Szent Istvan University	Hungary
79553	17	26	17	27	I have no reference where coal phsing out as allow better access to energy. Could you reference?	Deleted.	Marc Daras	CentraleSupelecAlumni	France
79555	17	26	17	27	strong policy choices in favor of air quality and human health, or climate change by internalising externalities to increase the price of coal or by regulation.	Repeated with main texts, deleted.	Marc Daras	CentraleSupelecAlumni	France
1431	17		17		figure 6.2 has low quality	Accepted and updated.	Hamideh Dalaei	climatologist at Islamic Republic of IRAN Meteorological Organisation	Iran
3189	17		17		figure 6.2 has low quality. It should be noted that there are low quality figures in the IPCC Chapters as usual.	Accepted and updated.	Hamideh Dalaei	climatologist at Islamic Republic of IRAN Meteorological Organisation	Iran

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
43427	17		17		figure 6.2 has low quality. It should be noted that there are low quality figures in the IPCC Chapters as usual.	Accepted and updated.	sadegh zeyaeyan	Head of national center for forecasting and weather hazards management of Islamic Republic of Iran Meteorological Organization (IRIMO)	Iran
50333	17		17		figure 6.2 has low quality. It should be noted that there are low quality figures in the IPCC Chapters as usual.	Accepted and updated.	Government of Iran	Islamic Republic of Iran Meteorological Organization (IRIMO)	Iran
8885	18	3	18	4	Note that in 2020 power plant manufacturers (GE, Siemens) announced their exit from building new coal plants.	Noted. Added one sentence of subnational actions on coal.	Seth Dunn	ServiceMax	United States of America
857	18	4		5	number of European countries are part of the Powering Past Coal Alliance (PPCA) and havecommitted to phase-out coal on or before 2030'. It is by 2031 for OECD (most of European countries), and eastern europe and former soviet union. Re-evaluate it.	Noted. Updated texts regarding more recent development of the PPCA.	Alok Dhaundiyal	Szent Istvan University	Hungary
20081	18	4	18	16	Greece, also a member of PPCA, traditionally relied on coal (lignite) with around 4GW installed capacity (almost 10% of PPCA) with the recent NCEP pledging for a coal phase-out until 2028. With Greece exiting a long period of reccession perfoming a just transition can be challenging especially in coal-dependent regions of the country (Nikas et al., 2020): -Nikas, A., Neofytou, H., Karamaneas, A., Koasidis, K., & Psarras, J. (2020). Sustainable and socially just transition to a post-lignite era in Greece: a multi-level perspective. Energy Sources, Part B: Economics, Planning, and Policy, 15(10-12), 513-544.	Noted. Updated texts regarding more recent development of the PPCA.	Haris Doukas	National Technical University of Athens, Greece	Greece
63629	18	4	18	44	Wood pellets are used in multiple countries (e.g. UK, Japan, Korea) to phase out coal, either through full conversion of power plants or co-firing.	Noted. Added one sentence summarising different strategies of phasing out coal plants.	Government of Canada	Environment and Climate Change Canada	Canada
64315	18	4	18	16	The UK has made considerable progress in decommissioning its coal plant as a result of the European Union Emissionis Trading Scheme, and policies and actions resulting from the Climate Change Act 2008,	Noted.	Peter North	Imperial College (part-time PhD student) /Calorem Ltd	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
76391	18	4	18	16	This section has not recognised the substantial efforts Poland is making to wean itself off coal. The following text comes from the World Nuclear Association database. In May 2011 the Polish parliament decisively passed – by 407 votes to 2 – legislation amending the country's Nuclear Energy Law to "provide for the establishment of a transparent and stable regulatory framework covering the entire investment process" by the National Atomic Energy Agency (Panstwowa Agencja Atomistyki, PAA), which will oversee construction of the plants. It covers plant operation and the management of radioactive waste and used fuel. Further legislation was passed at the end of June. In November 2018, the Ministry of Energy published its draft Energy Policy of Poland until 2040 (EPP2040) for public consultation. The document reaffirmed plans to develop 6-9 GWe of nuclear energy. This was confirmed in a revised version in May 2019, forecasting the completion of the first of six 1-1.5 GWe units in 2033, with each successive unit to follow every two years, replacing coal-fired generation. The ministry estimated the cost of constructing nuclear at €4.66 million/MWe (Zloty 20 million/MW). In October 2020, Poland's Ministry of Climate announced an acceleration of the plans, calling for technology selection in 2021, and signing of the final contract for the first plant in 2022. The country's cabinet formally adopted the energy policy in February 2021. The government is holding talks with several potential partners for the investment, with the expectation that a foreign partner would hold a significant stake as well as supplying the reactor technology. In June 2019, Poland signed a bilateral agreement on civil nuclear cooperation with the USA. In November 2019, the Polish government indicated that it planned to set up a special-purpose company in which it would own a 51% stake, with the remaining 49% held by a foreign partner. The financing structure for new plants was expected to be confirmed in 2020, and in April 2020 PGE reiterated that it would be unable to finance the plant from its own balance sheet. GErmany on	Noted. Added one summary sentence of subnational actions on coal.	Robert Parker	Nuclear for Climate Australia	Australia
63631	18	8	18	8	Germany is a member of the PPCA since Jan 2019, with a adjusted timeline of 2038. https://poweringpastcoal.org/news/PPCA-news/membership-options-national-governments-declaration-group	Noted. Updated texts regarding more recent development of the PPCA.	Government of Canada	Environment and Climate Change Canada	Canada
5331	18	10	18	10	You state that Poland has not set any target, which is not totally true. Poland has confirm her Will to decrease coal consumption and set objectives for nuclear plants construction.	Noted and clarified in the texts.	Michel SIMON	Retraité/ Pdt d'association	France
43547	18	10	18	11	Germany passed a specific law on phase out in July 2020, sets 2038 as the latest deadline	Noted. Updated texts regarding more recent development of the PPCA.	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy
45473	18	10	18	10	Poland has not set a 100% phase out target, but is clearly planning to very substantially cut coal use. See this news item, underlying policy paper will probably give more detail. https://www.reuters.com/article/us-poland-coal-idUSKBN25Z1G3	Noted and clarified in the texts.	Kornelis Blok	Delft University of Technology	Netherlands

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
20217	18	14	18	16	The point on economic development does not necessarily stand, and in some Member States a socially just transition for workers will be harder than reported, e.g. in Greece, which makes up a significant part of PPCA: - Nikas, A., Neofytou, H., Karamaneas, A., Koasidis, K., & Psarras, J. (2020). Sustainable and socially just transition to a post-lignite era in Greece: a multi-level perspective. Energy Sources, Part B: Economics, Planning, and Policy, 15(10-12), 513-544. The same can be said for non-PPCA members that expectedly make up for larger shares of European coal and, as a result, the political climate debate is not the same as in the average EU country, like highly coal-relying Poland. A very good case about the challenges behind ensuring equal opportunities for coal workers into greener jobs in Poland can be found in - Antosiewicz, M., Nikas, A., Szpor, A., Witajewski-Baltvilks, J., & Doukas, H. (2020). Pathways for the transition of the Polish power sector and associated risks. Environmental Innovation and Societal Transitions, 35, 271-291.	Noted. Just transition challenge is acknowledged in the revision.	Nikas Alexandros	National Technical University of Athens	Greece
861	18	17			Coal is also being phased-out in North America.' Time frame and support the statement with proof.	Updated the texts.	Alok Dhaundiyal	Szent Istvan University	Hungary
64609	18	17	18	17	the term "coal phase-out" is not appropriate here, as it suggests a deliberate effort to that end. As mentioned that is not the case, to the contrary since the 2016 administration, but a cost driven business opportunity offered by cheap gas.	Updated the texts.	Government of Netherlands	Ministry of Economic Affairs and Climate Policy	Netherlands
85337	18	17	18	19	this reference to the US will need updating with the Biden government strategy	Updated the texts to reflect recent policy development in the U.S.	Linda Hancock	Deakin University	Australia
77213	18	20	18	21	In the sentence "This commitment, combined with cheap renewables or environmental regulations in particular regions", which refers to Canada, should include at first "nuclear life extension and new builds", as these are the main assets supporting coal phase-out in that country.	Rejected. Missing reference to support the suggested statement	Giacomo Grasso	ENEA	Italy
79557	18	24			the reduction of cooling water depends of the alternative mean of production use. If it is an other thermal power plant the need of cooling water is similar, depending of efficiency (which can be very high with modern coal power plant, super critical). So I suggest the wording "local cooling water use"	Clarified this is a statement of observation in the U.S.	Marc Daras	CentraleSupelecAlumni	France
79559	18	25	18	30	The concern for workers is one of the reason of delaying phase out in many countries. The exemple of US is pertinent as volume are concerned and couls be found in germany, poland or china with different policies. However, the following sentence promoting emploiement in BECCS is not pertinenet because the volume and the phasing is not pertinent; such activities wil be important in volume if it comes to life after 2030 and more largely after 2040, while the questionof employement is present. One should consider social programme, or formation to new activities. Reference to present policies in Germany, or past policies in other countries may be more significant.	Revised the sentence and deleted the example of BECCS.	Marc Daras	CentraleSupelecAlumni	France
55625	18	26	18	26	It can be noted that the loss of "30,000 jobs" is several times fewer jobs than the jobs lost in coal production with the shift from underground mining to western surface mining during the 1980s and 1990s, e.g., from Wikipedia “Average annual number of coal miners, 1985 to 2015 (Data from St. Louis Federal Reserve Board)” https://en.wikipedia.org/wiki/Coal_mining_in_the_United_States	Noted. Thank you for the useful context.	Government of United States of America	U.S. Department of State	United States of America
859	18	31		32	no committed plans to phase out coal' Literature gap	Clarified. It refers to no officially annouced coal phaseout target.	Alok Dhaundiyal	Szent Istvan University	Hungary

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
15245	18	31	18	31	In order to maintain the consistency of the regional expressions, it is suggested to replace "China and India" with "Asia".	Accepted.	Government of China	China Meteorological Administration	China
15247	18	31	18	33	Line 31 states that China has no committed plans to phase out coal, which does not tally with the facts. Since 2013, the Chinese government has launched a series of policies to phase out coal, such as China's "13th Five-Year Plan for Energy", which clearly proposes to control the total coal consumption to 4.1 billion tons of raw coal by 2020. It is suggested to delete “and have no committed plans to phase out coal.” and include “Since 2013, the Chinese government has formulated a series of policies to promote the withdrawal of coal.” before “China” in Line33. List of documents launched by China to phase out coal: National Development and Reform Commission of China, December 2016, "13th Five-Year Plan for Energy ". The plan states that the main objectives of energy development in 2020 include controlling coal targets, with total coal consumption controlled to within 4.1 billion tons. http://www.nea.gov.cn/135989417_14846217874961n.pdf Central Committee of the Communist Party of China and the State Council of China, June 16, 2018, Opinions of the Central Committee of the Communist Party of China and the State Council on Comprehensively Strengthening Ecological and Environmental Protection and Resolutely Fighting the Battle of Pollution Prevention and Control http://www.gov.cn/zhengce/2018-06/24/content_5300953.htm The State Council of China, September 10, 2013, Air Pollution Prevention and Control Action Plan	Clarified and updated Chinese coal policies	Government of China	China Meteorological Administration	China
37095	18	31	18	32	The first statement is wrong. Indian has committed to Paris agreement and GoI strongly pursuing with clean and green energy sources, for example expansion of nuclear and renewables. Old coal plants are not being replaced by new coal plants.	Updated the texts of India coal policies.	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
49759	18	31	18	32	The statement should be removed. India prepared national action plan for climate change long back and is implementing various policies on mitigation actions. As a developing country India is facing tremendous challenges to provide electricity to all as quickly as possible at affordable cost as well as to tackle GHG emission scenario arising out of coal combustion, the cheapest way electricity production. In spite of substantial growth in renewable energy sector in India the coal is likely to remain in the mainstay of energy production in next few decades for sustainable economic growth of the country. Ref: BUR3 to UNFCCC in the following Link: https://unfccc.int/sites/default/files/resource/INDIA_%20BUR-3_20.02.2021_High.pdf	Updated the texts of India coal policies.	PINAKI SARKAR	CSIR-CIMFR, Dhanbad	India
55627	18	31	18	44	Adding a bullet here on broader SE Asia would be valuable give the situations in Vietnam, Indonesia, etc.	Noted and changed the China and India paragraph to Asia.	Government of United States of America	U.S. Department of State	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
61209	18	31	18	44	There is no uniformity in the regional classification of Box 6.2. Others are based on states, while India and China are compared in the form of countries, and the example of China is not completely consistent with the facts of China. It is recommended to delete or modify	Noted and changed the China and India paragraph to Asia.	Jianguo WU	chinese research academy of environmental sciences	China
20219	18	32	18	33	See also Rauner, S., Bauer, N., Dirnaichner, A., Van Dingenen, R., Mutel, C., & Luderer, G. (2020). Coal-exit health and environmental damage reductions outweigh economic impacts. Nature Climate Change, 10(4), 308-312. (China): Yang, X., Pang, J., Teng, F., Gong, R., & Springer, C. (2021). The environmental co-benefit and economic impact of China's low-carbon pathways: Evidence from linking bottom-up and top-down models. Renewable and Sustainable Energy Reviews, 136, 110438. (India): Gupta, A., & Spears, D. (2017). Health externalities of India's expansion of coal plants: Evidence from a national panel of 40,000 households. Journal of environmental economics and management, 86, 262-276.	Noted. Thank you for the literature.	Nikas Alexandros	National Technical University of Athens	Greece
48737	18	33	18	35	Suggest to change “China announced a coal moratorium in 2015, which was also predicated on cutting overcapacity (Blondeel and Van de Graaf 2018).” to “China announced a coal moratorium in 2015, which was also predicated on cutting overcapacity (Blondeel and Van de Graaf 2018), and introduced coal total consumption and share limitation targets in five-year plans”. Reason: Coal total consumption and share control is one of the most important coal policies in China - suggest to add here to make the description on China's coal policy more objective and comprehensive. Supporting document: China's 13th 5-Year-Plan on Energy (https://www.ndrc.gov.cn/xxgk/zcfb/tz/201701/t20170117_962873.html)	Updated the texts of Chinese coal policies	Qi An	Energy Research Institute, National Development and Reform Commission of China	China
863	18	34			Coal moratorium in 2015 ??? It is on mining I think. They will not approve any coal minning projects henceforth (2015). But on coal use, ? Why do the new technology develop to revive the coal-based plants? Correct it.	Clarified. It was on a list of coal power projects.	Alok Dhaundiyal	Szent Istvan University	Hungary
17331	18	39	18	39	"India has retired about 8.5 GW of inefficient and old coal based plants" Not particularly useful piece of data. How much did India added in the same period? The same for China: please add number of coal capacities added in the past 5 (or 10) years.	Accepted. The paragraph on Asia is revised.	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
7849	18	43	18	43	and would thus would face -- repeat of would	Accepted and revised.	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
79561	18	43	18	44	"larger risk of stranded assets" should read " stranded assets loss"	Noted and revised.	Marc Daras	CentraleSupelecAlumni	France
17333	18	47	18	47	"In South Africa, employment…" empoyment in South Africa coal sector is irrelevant. Give some numbers of coal plants built and planned for the whole continent.	Rejected. South Africa is a main coal producer and employment in the mining sector is much larger than in the power sector.	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
865	18	48			since the 1980s, fall	Noted and revised.	Alok Dhaundiyal	Szent Istvan University	Hungary
37097	18		18		If India phases out all coal plants assuming no new build and their design lives are exhausted,	Rejected. Faster retirement is needed to meet 1.5C	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India

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37099	18		18		at least 200 GW primary base load power has to be replaced by green sources of energy.	Noted.	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
50877	19	1	19	3	Does sentence need correcting? Suggest: "Given income inequality in South Africa, a sustainable and just transition for these workers [remove:is essential] through reemployment in the growing renewable sector will be critical"	Accepted and revised.	Bianca Wernecke	South African Medical Research Council	South Africa
43549	19	2	19	3	English usage: drop either "is essential" or "will be critical" otherwise the sentence doesn't work	Accepted and revised.	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy
867	19	4			remain (subheading)	Noted. The subheading was edited with revisions	Alok Dhaundiyal	Szent Istvan University	Hungary
55629	19	4	20	26	Sections 6.3.5 and 6.3.6 compare deployment with capacity expansion, and this apples-to-oranges comparison offers a distorted view of what is going on. Recommend providing five numbers for each technology type, for as uniform a time period as possible (and preferably for a decade or so to avoid the noise of interannual fluctuations). These numbers could be: 1. Additional capacity deployed. 2. Capacity factor (ratio of generation to capacity; important because definition of capacity differs across technology classes) 3. New generation (capacity factor x additional capacity) 4. Retirements of existing generation capacity 5. Net change in generation (or perhaps capacity). This section gives the impression that solar PV and wind are being deployed at a rate that is not comparable to other technologies, but technologies that have been around for a long time have more retirements than wind or solar. Reporting net capacity expansion obscures the understanding of new deployments. For context, it might be nice if this table included not only low-carbon technologies but also gas, oil, and coal for context. For example, it would be very interesting to know how new solar and wind generation compares with new natural gas generation. Generation is a good way to compare across technologies since capacity factors differ so greatly across technologies.	Section 6.3.5 aims to cover the recent trends (since AR5) in the deployment of solar and wind technologies. The comparisons with fossil fuels and other generation technologies are covered in subsequent sections. We have modified the figure 6.6 to include the share of solar and wind in total generation which will give a better idea about the role solar and wind are playing in the overall generation. The last paragraph also puts the current trends in perspective to anticipate future evolution in these technologies. Section 6.4 further covers it in detail.	Government of United States of America	U.S. Department of State	United States of America
78585	19	4	19	29	a most important information is missing, and most important for the context of the message: in 2019 77% (!) of all new built power capacity had been renewable (UNEP/BNEF - fig. 17 - https://wedocs.unep.org/bitstream/handle/20.500.11822/32700/GTR20.pdf), this key information shall be added for providing the context how fast the transition happens right now	We have reported the annual growth rates for solar and wind since 2015 which covers the point of rapid growth rates in these technologies. Further discussion could not be accomodated here due to space constaints but in covered in section 6.4	Christian Breyer	LUT University	Finland
79563	19	4			The title should read " Solar and wind power plants" because not only PV is considered (CSP) and it concerns solely power plant .	Suggestion taken into account in the modified title	Marc Daras	CentraleSupelecAlumni	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
85433	19	4	19	5	The development in solar and wind since AR5 has been HUGE. Especially the price decrease. In my modelling comunity it's probably the biggest story in the entire AR6. That doesn't mean we should suggest that no more policy support is needed but this paragraph is again formulated in a thoroughly glass-half-empty style. Couldn't the AR6 emphasize a bit more what is going right and how we get more of that instead of just providing grocery lists with complaints? Also seems there is a law in AR6 that all positive news needs to be played down and followed by a sentence starting with a word like "despite" so you leave the reader on a downer. If you want people to move - as esp. WG3 should aim to do - you should give a little bit more attention to how you deliver the message. Don't we want to motivate people to avoid catastrophe by making them work towards a better future? Or do we just want to make them feel down and stay in bed? So instead of saying "Solar PV and Wind has grown but remains low" you could also say "The cost of solar and wind has plummeted and their share is small but growing exponentially". The second formulation puts your mind on a positive trajectory and gives you energy. Doesn't the AR6 want to achieve that?	Noted. The cost decline is reported here and discussed in detail in section 6.4	Auke Hoekstra	Eindhoven University of Technology	Netherlands
85435	19	4	19	5	I think you mean growth 'per year'. That is left out in multiple places in the chapter and makes all the difference. Also, such a growth is by definition exponential, and since people are prone to underestimate exponential growth unless it's very explicitly pointed out to them it would be good to add that term in the sencence I think.	Noted. Text was modified for clarity as suggested.	Auke Hoekstra	Eindhoven University of Technology	Netherlands
875	19	6		19	discuss about offshore wind capacity as well in this section.	Share of offshore wind is reflected in the text now. Detailed discussion on offshore wind is in section 6.4	Alok Dhaundiyal	Szent Istvan University	Hungary
28941	19	6	19	19	It seams that fonts change in size within this text passage.	Changes made in current draft. It will be further addressed during final editing of the chapter.	Fabian Heymann	INESC TEC	Switzerland
42971	19	6	19	20	Each of the growth and deployment elements are presented individually. In reality they are part of integrated system planning. An important enabler for Solar PV and wind is the inclusion of backstopping technology or the risk of an unstable electricity grid because of the intermittent nature of these renewables. Different jurisdictions have addressed this challenge in various ways. Since battery technology is not yet cost effective at scale, many jurisdictions such as Ontario - Canada have backstopped wind and solar with the development of new natural gas plants. California has created an Energy Imbalance Market drawing on resources across western North America to backstop wind and solar. In many jurisdictions this also means that it is common for natural gas power plants to be running idle or at minimum loading when there is strong wind/solar expected to be on the grid.	Noted. This section is restricted to recent trends in technology deployment but a detailed discussion on system integration is covered in section 6.4.	Kurt Kornelsen	Ontario Power Generation	Canada
43551	19	6	19	7	Is this cumulated growth since 2015 to when? Or per year? Please specify	Noted. Text modified for more clarity	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy
84287	19	6	19	7	Besides the growth, insert the reached capacity worlwide.	The reached capacity is reflected in figure 6.6	Vincent MAZAURIC	Schneider Electric	France
869	19	7			the total	Text rewritten with modifications	Alok Dhaundiyal	Szent Istvan University	Hungary

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
1259	19	7	19	8	The calculation that solar and wind were <4% "contributions to total electricity" must be using primary energy. This is misleading. The sentence should be replaced with "Wind and solar generated about 7% of the total world electricity in 2018." Or, better yet: "Wind and solar generated 7.7% of the total world electricity in 2019." The numbers from the 2020 World Energy Outlook are 1273 and 1423 TWh from wind in 2018 and 2019 respectively. And 565 and 680 TWh from solar out of a total of 26,619 and 26, 942 TWh for 2018 and 2019, respectively. These numbers are consistent with the IRENA numbers presented in Fig. 6.6. If you are using primary energy, then you should identify a reasonable heat rate to apply to solar and wind, but it seems much more useful to quote the fraction of TWh generated rather than referring to the primary energy.	Noted and updated in the text	Sarah Kurtz	University of California Merced	United States of America
9803	19	7	19	8	please add reference	Noted. References added at appropriate places in the modified text	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
51351	19	7	19	8	However, their combined contributions to total electricity generated from all sources were about 7% in 2018.	Noted and updated in the text	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
20895	19	8	19	8	About "below 4% in [...]", please indicate respective contributions of solar and wind rather than their combined contributions.	Text updated with respective contributions of solar and wind	Government of France	Ministère de la Transition écologique et solidaire	France
37669	19	8	19	9	This is regrading continued use of the metric mevelised cost of electricity generation. This metric does not have any parameter to account for intermittency and overpredicts the benefit from soalr and wind. It was devised at a time when intermittent sources were not connected to the grid and was acceptable for comparing costs of despatchable sources having different lifetime. In view of introduction of intermittent sources to the grid, its continued use is scientifically incorrect and is leading to policy formulations that are untenable. Please advise readers to go in for system analysis in place of using LCOE. For details, please refer to P. Graham, Review of alternative methods of extending LCOE to include system costs, CSRIO, Australia, 2018.	LCOE was dropped from this text and the overall reductions in costs were reported instead. A detailed discussion on costs of solar and wind is covered in section 6.4 where the issue of LCOE is also discussed.	Ravi B Grover	Homi Bhabha National Institute	India
43863	19	8	19	10	What is the reason behind the lowering LCOE of solar PV and wind? It is important to discuss some reasons as to why such behavior happen. According to a 2020 publication by the IRENA [10], the LCOE of solar PV and wind decreased by 82% and 39%, respectively, from 2010 to 2018 due to technological advancements and expanding market due to increasing number of investments.	Noted. We have restrcited this section to reporting the recent trends due to space constraints. However, a detailed discussion on declining costs and underling reasons could be found in section 6.4	Vince Davidson Pacañot	University of the Philippines Diliman	Philippines
78587	19	8	19	8	the wind and solar PV share in electricity supply in 2019 had been almost 9% (REN21-2020 - fig. 10 - https://www.ren21.net/gsr-2020/), which is more than twice (!) the number of 4% shown. This false information shall be corrected.	Noted and updated in the text	Christian Breyer	LUT University	Finland
81055	19	8	19	8	It is worth noting that, if this 28% annual growth rate continued for another decade, their share would rise from 4% to 38% in 10 years (4*(1.28)^10). Quoting the current penetration without putting the ongoing growth in context may lead to an overly pessimistic view of the role PV in particular, and renewables in general, will play in mitigation strategies in the coming decade.	The purpose of this section is to just report the recent trends. The last paragraph gives a glimpse of the future trends and more detialed discussion on these trends and future projections is covered in section 6.4	Aaron Barkhouse	SunPower Corporation	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
84289	19	8	19	9	LCOE is just one input for renewable assessment. Externalities such as back-up or storage or inertia or ICT-control capabilities should be also taken into account according to a given level of LOLE to provide a fair comparison with dispatchable energy sources. From a Life Cycle Assessement point of view, the EROI (Energy Return on Investment) should be also considered.	LCOE was dropped from this text and the overall reductions in costs were reported instead. A detailed discussion on costs of solar and wind is covered in section 6.4 where the issue of LCOE is also discussed.	Vincent MAZAURIC	Schneider Electric	France
873	19	10		11	Mention about Scotland onshore wind projects. This country is the good example of utilising renewable sources.	Noted. We have covered regional trends in this section but discussing specific country level examples will not be possible due to space constraints	Alok Dhaundiyal	Szent Istvan University	Hungary
2643	19	11	19	12	It does not become clear that the 622 GW only refer to wind. Solar is another 586GW in 2019 according to IRENA, Renewable Energy Capacity Statistics 2020.	Noted and updated figures reported in the text now	Jan Wohland	ETH Zurich	Switzerland
10915	19	11	19	11	delete ")" in "Total global cumulative capacity was 622 GW in 2019)"	Noted and edited in updated text.	Dong-Woon NOH	Korea Energy Economics Institute	Republic of Korea
16339	19	11	19	11	delete ")" in "Total global cumulative capacity was 622 GW in 2019)"	Noted and edited in updated text.	Government of Republic of Korea	Korea Meteorological Administration (KMA)	Republic of Korea
71537	19	11	19	11	What is meant by commercial wind plants? Plants without subsidies? Or operational plants? This should be further refined.	We have reported the total wind capacity as reported in IRENA's renewable capapcity statistics 2021. The text and figures were updated for clarification	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
15249	19	12	19	13	The conclusion fails to reflect the latest trends. On January 20, 2021, the National Energy Administration of China released the national electricity industry statistics for 2020, according to which the new installations of wind power and PV in China reached 71.67 million kW and 48.2 million kW respectively in 2020, especially the new installations of wind power increased by 177% year-on-year compared to the previous year, and the new additions exceeded the sum of the three-year increments in 2017, 2018 and 2019 and even nearly 12 million kilowatts higher than the 60 million kilowatts of global new wind power in 2019. It is suggested to provide the data updated to 2020 and change "led by China but the growth has slowed down post-2015" to “led by China with annual newly installed capacity of solar and wind 60GW to 90GW per year, and with a breakthrough about 120GW in 2020.” Supporting literature: National electricity industry statistics for 2020 released by the National Energy Administration of China, 2021, http://www.nea.gov.cn/2021-01/20/c_139683739.htm	Noted. The suggestion was taken into account and the figures were updated based onlatest statistics reported by IRENA, BP and IEA energy statistics	Government of China	China Meteorological Administration	China
79565	19	13			This § should refer only to PV for clarity. IEA key stat gives 495GW of solar PV, and 554 TWh of production (nota production should be indicated for wind too) . The imporatnce of China is mentionned, but not of US, as for wind. See REN21, GSR 2020. and IEA key stat. It should ne mentionned the imporatncetaken by PV power plant versus household on PV market.	Noted. Text updated for further clarification	Marc Daras	CentraleSupelecAlumni	France
55631	19	14	19	16	What was Europe's previous share of total global cumulative photovoltaic capacity? This sentences describes a decline to a new value, but not what original or high point was for this share.	Noted. Text updated to report the solar and wind's previous shares for Europe	Government of United States of America	U.S. Department of State	United States of America
71539	19	14	19	14	Given the higher energy demand in Asia it is clear that the relative share of Europe will further decrease. Maybe this can be added to the paragraph?	Noted. The future projections are discussed in section 6.4	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
17481	19	17	19	17	"Concentrating solar power (CSP)", given that it is the first time to be mentioned	Noted and added	Alaa Al Khourdajie	IPCC	United Kingdom (of Great Britain and Northern Ireland)
79567	19	17			On CSP installed capacity are 6.2 GW (REN21). The importance of storage should be mentionned as a key factor for CSP.	Noted. This section only reportes the recent trends. More discussion on CSP and its enabling factors discussed in section 6.4	Marc Daras	CentraleSupelecAlumni	France
9805	19	18	19	19	please add reference	Noted. References added at appropriate places in the modified text	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
55633	19	18	19	19	The sentence states that 75% of production is in the U.S. and Spain, but it is unclear if this refers to all solar, solar PV, or CSP since this paragraph covers both solar PV and CSP.	Text modified and the statistics were dropped from this section. More discussion on CSP is in section 6.4	Government of United States of America	U.S. Department of State	United States of America
871	19	19			the total	Noted	Alok Dhaundiyal	Szent Istvan University	Hungary
17335	19	21	19	21	Fig. 6.6 units for electricity generation TWh - TWh/year	Noted. This figure was modified to report the share of solar and wind in total electricity generation to give a perspective on solar and wind's performance with respect to other technologies	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
7851	19	22	19	23	Units should be GW yr-1 rather than MW yr-1, and TWh rather than GWh	Noted. We have modified this figure to report cumulative installed capacity (GW) on primary Y-axis and the share of solar and wind in total electricity generation on the secondary Y-axis	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
5333	19	25	19	26	To limit warming under 2°C, what is important is the development on non fossil fuel production. Part of the solution is laying with wind and solar. The other part is expected from nuclear. This should be mentioned.	Noted. Futher discussion on this is covered in other sections as mentioned in the text	Michel SIMON	Retraité/ Pdt d'association	France
43553	19	25	19	25	Replace "remain" with "remains"	Noted and corrected in modified text	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy
77215	19	25	19	27	Refrring to growth rates, when the reference overall share is so low, seems naif, since it is hardly projectable to higher penetrations. A reference to capacity additions would have been more objective, even though the conclusion could not be the same.	Capacity addition is evident from the figure 6.6 which along with the growth rates captures the trends in solar and wind deployments	Giacomo Grasso	ENEA	Italy
52271	19	27			The critical question will be whether these growth rates can be maintained at the necessary levels, or whether concerns with retiring fossil power or challenges with integration of renewables will slow or limit this growth. The capital from FF drives growth of renewables as well and this needs to be consdiered in the discussion too.	Noted. Futher discussion on this is covered in other sections as mentioned in the text	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
71541	19	28	19	29	Maybe add a phrase that some countries have already reached very high RES shares in the electricity system - i.e. in principle the challenges of integration can be overcome. Of course they could decrease the growth of RES but they are not so much of a technical nature. I am not sure how to adapt this but would prefer a different wording in order to avoid that grid operators reading the text (who are always critical about the integration of RES) feel confirmed in their opinion.	The discussion on system integration is beyond the scope of this section but is covered in detail in sections 6.4	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
8887	19	29	19	30	Note IEA Renewables 2020 (November 2020) that renewables for electricity grew 7% despite pandemic.	Noted and updated figures reported in the text now	Seth Dunn	ServiceMax	United States of America
55635	19	29	19	29	Recommend clarifying this sentence to specify challenges with integration of variable renewables. Dispatchable renewable generation from hydropower or geothermal typically do not have integration problems, rather they facilitate and enable the integration of variable generation technologies and should therefore be acknowledged and given credit for doing so.	The discussion on system integration is beyond the scope of this section but is covered in detail in sections 6.4	Government of United States of America	U.S. Department of State	United States of America
27715	19		19		Figure 6.6: presents capacity addition in GW or in MW? Speficy also which data is shown in the LHS and RHS axes.	Noted. We have modified this figure to report cumulative installed capacity (GW) on primary Y-axis and the share of solar and wind in total electricity generation on the secondary Y-axis	Eleni Kaditi	Organization of the Petroleum Exporting Countries, OPEC	Austria
37671	20	1	20	1	Why there is no section on deplyment of nuclear?	The growth in nuclear was stagnant in the past decade hence this was not covered in detail in section 6.3 which focuses on recent trends. However, nuclear is discussed in detail in subsequent sections, particularly in section 6.4.2.4	Ravi B Grover	Homi Bhabha National Institute	India
48113	20	2	20	3	"…low and negative carbon energy fuels…such as modern bioenergy." This statement is just not true. Modern bioenergy is not low carbon. It may be lower carbon than fossil fuels but that does not make it low carbon. Regardless, it also produces pollution when burned so its social cost is orders of magnitude higher than of clean, renewable energy sources (wind, water, solar). Please do not include bioenergy among viable solutions to global warming. It is not needed, as shown in numerous studies, including this Jacobson, M.Z., M.A. Delucchi, M.A. Cameron, S.J. Coughlin, C. Hay, I.P. Manogaran, Y. Shu, and A.-K. von Krauland, Impacts of Green New Deal energy plans on grid stability, costs, jobs, health, and climate in 143 countries, One Earth, 1, 449-463, doi:10.1016/j.oneear.2019.12.003, 2019.	Noted. The issue of bioenergy as a low carbon source is discussed in detail in section 6.4.2.6	Mark Jacobson	Stanford University	United States of America
17337	20	3	20	5	Wrong claim: "Apart from solar PV and wind, low- and negative-carbon energy fuels and technologies such as hydropower, modern bioenergy, geothermal, marine, and carbon capture and storage (CCS) experienced limited deployment over the last decade (Lovins et al. 2018)." According to BP 2020 data hydropower experienced an increase comparable to wind and larger than solar between 2009 and 2019. Wind: 276->1430 TWh, Solar: 21-724 TWh, Hydro: 3252->4222 TWh.	Growth in hydropower deployment was around 2.7% between 2010 and 2019 compared to 33% and 15% for solar and wind during this period (as per IEA WEO 2020 and IRENA Electricity Statistics 2021). According to BP statsitics the share of hydropower in total electricity generation remained around 16-17% between 2010-20. Our limited point here is that hydropower growth has been slower than solar and wind in recent years.	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
42973	20	3	20	4	Should nuclear not be considered in this list?	It is considered and also discussed in detail in subsequent sections, particularly in section 6.4.2.4	Kurt Kornelsen	Ontario Power Generation	Canada

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
55637	20	3	20	3	According to EIA (https://www.iaea.org/newscenter/news/iaea-releases-2019-data-on-nuclear-power-plants-operating-experience), 57.7 GWe of generation came on line between 2010 and 2019. With a capacity factor of 85.9% this works out to 434.5 TWh/yr generation by new nuclear deployment over the period 2010-2019. It is hard to read the exact numbers from Figure 6.6 but the increase in generation from solar between 2010-2019 is on the order of 500 TWh. Thus the amount of new generation by new nuclear and new solar are comparable. The difference is that solar does not have as much old stock going off line, but in terms of generation from new deployment, solar and nuclear are comparable. Therefore, the sentence should instead read: ""Apart from solar PV, wind, and nuclear power, low- and negative-carbon energy fuels and technologies such as hydropower, modern bioenergy, geothermal, marine, and carbon capture and storage (CCS) experienced limited deployment over the last decade."" It is important that stakeholders understand that nuclear deployment is occurring at a rate similar to solar deployment.	Noted. Given that we are tracking the growth in deployment in recent years, this has been edited to "limited growth in deployment since 2015".	Government of United States of America	U.S. Department of State	United States of America
71543	20	3	20	4	It seems odd that solarthermal energy is mentioned in the previous subchapter rather than here, as this technology also experiences low growth I think.	Subsection 6.3.5 was renamed to include all solar and wind technologies. It now mentions the low growth in CSP compated to PV technologies. Subsection 6.3.6 now captures recent trends in all low carbon technologies apart from solar and wind.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
77217	20	3	20	4	It could be more interesting to include a mention to nuclear, in this list which goes even to marine energy, given their extremely different contributions (actual and potential).	It is mentioned and also discussed in detail in subsequent sections, particularly in section 6.4.2.4	Giacomo Grasso	ENEA	Italy
78497	20	3	20	5	This statement is not correct: "Apart from solar PV and wind, low- and negative-carbon energy fuels and technologies such as hydropower, modern bioenergy, geothermal, marine, and carbon capture and storage (CCS) experienced limited deployment over the last decade (Lovins et al. 2018)." According to BP 2020 data hydropower experienced an increase comparable to wind and larger than solar between 2009 and 2019. Wind: 276->1430 TWh, Solar: 21-724 TWh, Hydro: 3252->4222 TWh.	Please refer to response to identical comment 17337	Tomaž Žagar	Faculty for Energy Technology, University of Maribor	Slovenia

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
80629	20	3	20	5	Bioenergy does not belong to the category of low- and negative-carbon energy fuels and technologies. In fact, bioenergy, especially harvesting forest biomass for energy, is not carbon neutral in the near-term—with a carbon deficit for many years, generally several decades to a century—that is crucial for mitigating emissions and avoiding hitting the 1.5°C mark. Burning forest biomass for power generation emits more CO2 per unit of final energy than burning fossil fuels. Leturcq, P. (2020) GHG Displacement Factors of Harvested Wood Products: the Myth of Substitution, Nature Scientific Reports 10:1–9; Mary S. Booth, Not carbon neutral: Assessing the net emissions impact of residues burned for bioenergy, Environ. Res. Lett. 13 (21 February 2018); Sterman J. D., et al. (2018) Does replacing coal with wood lower CO2 emissions? Dynamic lifecycle analysis of wood bioenergy, Envtl. Research Letters 13(015007):1–10, 1 ("We simulate substitution of wood for coal in power generation, estimating the parameters governing NPP and other fluxes using data for forests in the eastern US and using published estimates for supply chain emissions. Because combustion and processing efficiencies for wood are less than coal, the immediate impact of substituting wood for coal is an increase in atmospheric CO2 relative to coal. The payback time for this carbon debt ranges from 44–104 years after clear-cut, depending on forest type—assuming the land remains forest. Surprisingly, replanting hardwood forests with fast-growing pine plantations raises the CO2 impact of wood because the equilibrium carbon density of plantations is lower than natural forests. Further, projected growth in wood harvest for bioenergy would increase atmospheric CO2 for at least a century because new carbon debt continuously exceeds NPP. Assuming biofuels are carbon neutral may worsen irreversible impacts of climate change before benefits accrue. Instead, explicit dynamic models should be used to assess the climate impacts of biofuels.").	Noted. Please refer to response to similar comment 48113	Durwood Zaelke	Institute for Governance & Sustainable Development	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
80773	20	3	20	5	Bioenergy does not belong to the category of low- and negative-carbon energy fuels and technologies. In fact, bioenergy, especially harvesting forest biomass for energy, is not carbon neutral in the near-term—with a carbon deficit for many years, generally several decades to a century—that is crucial for mitigating emissions and avoiding hitting the 1.5°C mark. Burning forest biomass for power generation emits more CO2 per unit of final energy than burning fossil fuels. Leturcq, P. (2020) GHG Displacement Factors of Harvested Wood Products: the Myth of Substitution, Nature Scientific Reports 10:1–9; Mary S. Booth, Not carbon neutral: Assessing the net emissions impact of residues burned for bioenergy, Environ. Res. Lett. 13 (21 February 2018); Sterman J. D., et al. (2018) Does replacing coal with wood lower CO2 emissions? Dynamic lifecycle analysis of wood bioenergy, Envtl. Research Letters 13(015007):1–10, 1 ("We simulate substitution of wood for coal in power generation, estimating the parameters governing NPP and other fluxes using data for forests in the eastern US and using published estimates for supply chain emissions. Because combustion and processing efficiencies for wood are less than coal, the immediate impact of substituting wood for coal is an increase in atmospheric CO2 relative to coal. The payback time for this carbon debt ranges from 44–104 years after clear-cut, depending on forest type—assuming the land remains forest. Surprisingly, replanting hardwood forests with fast-growing pine plantations raises the CO2 impact of wood because the equilibrium carbon density of plantations is lower than natural forests. Further, projected growth in wood harvest for bioenergy would increase atmospheric CO2 for at least a century because new carbon debt continuously exceeds NPP. Assuming biofuels are carbon neutral may worsen irreversible impacts of climate change before benefits accrue. Instead, explicit dynamic models should be used to assess the climate impacts of biofuels.").	Noted. Please refer to response to similar comment 48113	Gabrielle Dreyfus	Institute for Governance & Sustainable Development	United States of America
9147	20	4	20	4	Nuclear energy to be includeed the list of low- and negative-carbon energy fuels and technologies	It is included now and also discussed in detail in subsequent sections, particularly in section 6.4.2.4	Marin Constantin	RATEN ICN	Romania
15523	20	4	20	4	It is necessary to include nuclear power in the list, becouse it is mentioned in line 11 in the same page and its contribution to the production of primary energy is comparable to hydropower. https://www.world-nuclear.org/information-library/current-and-future-generation/nuclear-power-in-the-world-today.aspx	Noted. Please refer to response to similar comment 9147	Vladimir Kucinov	National Research Nuclear University "MEPHI" (Moslow Enginiring Physical Institute)	Russian Federation
31447	20	4	20	4	Nuclear energy is also a low carbon energy.	Noted. Please refer to response to similar comment 9147	Carolina Ahnert	Universidad Politécnica de Madrid	Spain
48115	20	4	20	4	Similarly, CCS is an opportunity cost and will not help in the solution to global warming. It always needs energyand equipment, so even using renewable energy to power it increases CO2, air pollution, and mining compared with using the same energy to replace fossil fuels Jacobson, M.Z., The health and climate impacts of carbon capture and direct air capture, Energy and Environmental Sciences, 12, 3567-3574, doi:10.1039/C9EE02709B, 2019.	Noted. We only mention the recent trends in this subsection due to space constraints. This issue of CCS is discussed in more detail in section 6.4.2.5.	Mark Jacobson	Stanford University	United States of America
51045	20	4	20	4	Nuclear energy should be included in the list of low- and negative-carbon energy fuels and technologies, among others because it is discussed later in this paragraph	Noted. Please refer to response to similar comment 9147	Eric PROUST	European Nuclear Society (ENS)	France
62113	20	4	20	4	please also add concentrating solar power (CSP)	CSP is convered in subsection 6.3.5	richard thonig	IASS Potsdam	Germany
79569	20	4			nuclear is missing	Noted. Please refer to response to similar comment 9147	Marc Daras	CentraleSupelecAlumni	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
82635	20	4	20	4	Include "nuclear" in list of low and negative-carbon energy fuels, as it is included in discussion.	Noted. Please refer to response to similar comment 9147	Jonathan Cobb	World Nuclear Association	United Kingdom (of Great Britain and Northern Ireland)
61757	20	5	20	5	Why is (Lovins et al., 2018, https://doi.org/https://doi.org/10.1016/j.erss.2018.01.005) cited for growth rates of various technologies over the original sources such as IEA and WEO? Replace it with the original ones. It also seems clear that (Lovins et al., 2018), aims at demoting the potential of nuclear energy to mitigate climate change. This is against IPCC recommendations, technology neutrality, rigorous scientific approach and sound climate policy. The paper continues the disputed exchange that happened in the open letters section of the journal Science (see https://doi.org/10.1126/science.aaf7131; https://doi.org/10.1126/science.aal1777; https://doi.org/10.1126/science.aal1808; https://doi.org/10.1126/science.aal2561).	Noted. This has been revised with citations to IEA and IRENA reports	Rauli Partanen	Think Atom	Finland
65791	20	5	20	5	Explain why (Lovins et al., 2018) is cited for growth rates of different technologies instead of the original data by NREL and BP reports (these are used in Lovins et al.). Replace the citation to (Lovins et al., 2018) by citations to the original research.	Noted. Please refer to response to similar comment 61757	Eero Hirvijoki	Aalto University	Finland
63633	20	7	20	8	Power generation, liquid biofuels and biogas do not represent applications for which most of the biomass is used for energy purposes. In industry, bioenergy accounts for the large majority of renewable heat consumption. Bioenergy also leads renewable heat consumption in buildings, used mainly in wood and pellet stoves and boilers as well as in district heating networks. Those applications should be added to section 6.3.6 under "advanced bioenergy". Refer to the IEA Renewables 2020 for more details.	Noted and text modified to include the suggestion	Government of Canada	Environment and Climate Change Canada	Canada
7853	20	8	20	8	modest' in deployment -- should be increases	Noted and edited during revision of the text	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
61557	20	8	20	14	reference to corporate plans for CCUS also useful. Also, both corporate and public plans for CCUS continue to be long term and vague and make a marginal increase to annual abatement. Discussion of this slow progress and the inertia such discussion of low carbon technology creates in fossil fuel and blue hydrogen sectors would be useful.	Noted. This subsection tracks recent trends but a detailed discussion on CCUS is covered in subsection 6.4.2.5	tom howes	International Energy Agency	France
14679	20	11	20	12	The time period related to the increase in capacity is not clear (1996 to 2019 like the % share of global electricity production ?).	Noted. This is modifed to reflect the recent change since 2015 for better comparison with other low carbon technologies. The modified text is "Global nuclear capacity has remained stagnant at around 400 GW in the last five years and its share in global total electricity generation has remained around 10% (IRENA, 2021; IEA, 2020)." More discussion and future projections of nuclear covered in subsection 6.4.2.4	Cécile Seguineaud	Indépendant consultant	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
14681	20	11	20	13	The data presented for nuclear electricity production do not allow a clear and objective comparison with the other sources of energy mentioned in this paragraph : it is expressed in % share of global electricity production, but in TWh for other sources. An harmonization would enable to compare rightly the order of magnitude involved for each energy source.	Please refer to response to similar comment 14679	Cécile Seguineaud	Indépendant consultant	France
61759	20	11	20	13	“Global nuclear power capacity has increased from 380 GWe to 400 GWe and its share of global electricity production, has continued its long decline, from a 17% share in 1996 to about 10% in 2019.” The “long decline” of nuclear share has not been happening to a significant scale for the last 8 years (since 2013), so this rhetoric is misleading. Please revise and supplement this with relevant information to give a better overview: “Nuclear energy production fell by roughly 300 TWh/a due to the premature, political closures after the Fukushima accident in 2011, but has since grown by a similar amount, +325 TWh/a between 2012 and 2019 (BP Energy Statistics 2020).	Please refer to response to similar comment 14679	Rauli Partanen	Think Atom	Finland
63635	20	11	20	13	The wording "has continued its long decline" is too strong and implies a sunsetting industry when nuclear has been shown to be part of the solution in many pathways to net zero. Market designs and policy decisions - not to do with the inherent technology - have been favouring renewable generation through subsidies and carbon emission requirements, however the non-emitting nature of nuclear continues to not be compensated for therefore its share of global generation has declined. We suggest taking out the "continued its long decline" therefore making the line "Global nuclear power capacity has increased from 380 GWe to 12 400 GWe and its share of global electricity production has decreased from a 17% share 13 in 1996 to about 10% in 2019 having been outpaced by renewable technologies."	Please refer to response to similar comment 14679	Government of Canada	Environment and Climate Change Canada	Canada

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
64233	20	11	20	13	Sorry - the "long decline of nuclear power" is a wrong statement in absolute terms. Facts and Figures from WNA source : "Plans For New Reactors Worldwide": • Nuclear power capacity worldwide is increasing steadily, with about 50 reactors under construction. • Most reactors on order or planned are in the Asian region, though there are major plans for new units in Russia. • Significant further capacity is being created by plant upgrading. • Plant lifetime extension programmes are maintaining capacity, particularly in the USA. Today there are about 440 nuclear power reactors operating in 32 countries plus Taiwan, with a combined capacity of about 400 GWe. In 2019 these provided 2657 TWh, over 10% of the world's electricity. About 50 power reactors are currently being constructed in 16 countries, notably China, India, Russia and the United Arab Emirates. Each year, the OECD's International Energy Agency (IEA) sets out the present situation as well as reference and other – particularly carbon reduction – scenarios in its World Energy Outlook (WEO) report. In the 2020 edition (WEO 2020), the IEA's 'Stated Policies Scenario' sees installed nuclear capacity growth of over 15% from 2019 to 2040 (reaching about 480 GWe). The scenario envisages a global nuclear electricity generation increase to 3073 TWh in 2030 and to 3475 TWh in 2040 (with the increase concentrated heavily in Asia, and in particular India and China). Nuclear's share of total output drops to 8% in 2040, compared with 10% in 2019. (Source = WNA website March 2021 - https://www.world-nuclear.org/information-library/current-and-future-generation/plans-for-new-reactors-worldwide.aspx	Please refer to response to similar comment 14679	Georges VAN GOETHEM	Royal Academy of Overseas Sciences (ARSOM - KAOW)	Belgium
74185	20	11	20	13	This sentence is too pessimistic about nuclear power. Nuclear has continued to grow and has had 7 straight years of increases but only has declined as a percentage of total generation due to the large amount of coal units in China, India and Indonesia, and natural gas units elsewhere- all of which are carbon intensive. https://www.world-nuclear.org/information-library/current-and-future-generation/nuclear-power-in-the-world-today.aspx	Please refer to response to similar comment 14679	Jeffrey Merrifield	Pillsbury Law Firm	United States of America
82637	20	11	20	13	The text portrays an ongoing decline from 1996 to present from 17% to 10%. Nuclear's share has stabilised at around 10-11% since 2015, due to a significant rise in nuclear generation since 2012. We therefore suggest the following: Nuclear's share of global electricity production, declined from a 17% share in 1996 to 10.5% in 2015. However, generation rose between 2015 to 2019, increasing from 2441 TWh yr-1 to 2657 TWh yr-1 (https://pris.iaea.org/PRIS/WorldStatistics/WorldTrendinElectricalProduction.aspx), and its share of global generation has remained between 10-11% over that period (https://ourworldindata.org/electricity-mix, BP Statistical Review of World Energy: https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html)	Please refer to response to similar comment 14679	Jonathan Cobb	World Nuclear Association	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
77219	20	12	20	13	"Long decline" does not reflect the increasing installed capacity and the even higher additional capacity that will be added by currently ongoing constructions. It is also hard to understand why for nuclear the share comparison dates back to 1996, while in the whole document the reference timeframe is 2010-2018… Accordingly, the following rephrasing is proposed: "[...400 GWe], with an increasing production which maintained the share of global electricity between 12% in 2010 to about 10% in 2019".	Please refer to response to similar comment 14679	Giacomo Grasso	ENEA	Italy
79571	20	12			Should add the production to be coherent with other energy; 2710TWh, 2018 from IEA key stat 2020	Please refer to response to similar comment 14679	Marc Daras	CentraleSupelecAlumni	France
9149	20	13	20	13	Please introduce the main reason for the reduction "to about 10% in 2019" of nuclear, and the increase of fossil-fuel generation during the period	Please refer to response to similar comment 14679	Marin Constantin	RATEN ICN	Romania
9807	20	13	20	15	please add reference	Reference added	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
15091	20	13	20	15	From the perspective of long-term development of CCS technology, CO2 utilization should not be ignored, which is also an important reason why Chinese scientists put forward and emphasized the concept of CCUs on the basis of CCS. Specific modification suggestions（It is recommended to change “Carbon capture and storage (CCS) remains largely in the research and demonstration phase without a meaningful impact on global CO2 emissions and no immediate prospects for large-scale deployment.” to “Carbon capture, utilization and storage (CCUS) remains largely in the research and demonstration phase without a meaningful impact on global CO2 emissions and no immediate prospects for large-scale deployment.”）。The supporting literature is as follows Wei, Y.-M., Kang, J.-N., Liu, L.-C. et al. (2021). A proposed global layout of carbon capture and storage in line with a 2 °C climate target. Nature Climate Chang, 1-7. https://doi.org/10.1038/s41558-020-00960-0	CCS is modified to CCUS in the revised text now. A detailed discussion on CCUS is covered in subsection 6.4.2.5	Guoquan HU	National Climate Center of China Meteorological Adminstration	China
15093	20	13	20	19	“Global CCS capacity was around 40 MtCO2 yr-1 in 2019, with large scale operational projects…. additional capacity of around 60 MtCO2 yr-1” It is recommended to update the data as “Global CCS capacity was around 40 MtCO2 yr-1 in 2020, with 26 commercial CCS facilities (Global CCS Institute 2020). There are now a number of ongoing and upcoming CCS projects (63 in 2020) with a capacity of more than 40 MtCO2 yr-1 from operation and in construction plants. Further, the plants under early and advanced stages of development in 2020 could provide additional capacity of around 73 MtCO2 yr-1 (Global CCS Institute 2020).”， And update the reference GCCSI,GLOBAL STATUS OF CCS 2020。The reasons are as follows: GCCSI report 2020 has been released. Supporting literature: Global CCS Institute (2020). The Global Status of CCS Report 2020. Access online: https://www.globalccsinstitute.com/resources/global-status-report/	The figures and text have been updated using the Global CCS Institute 2020 report	Guoquan HU	National Climate Center of China Meteorological Adminstration	China
17837	20	13	20	14	CCS is not "largely in the research and demonstration phase". There are currently 26 commercial CCS facilities operating globally and 40 million tonnes of CO2 is stored annually. Reference: Global Status of CCS Report 2020 globalccsinstitute.com/resources/global-status-report/	Please refer to response to similar comment 15093	Eve Tamme	Global CCS Institute	Belgium
20897	20	13	20	13	About "[...] about 10% in 2019.", suggestion add: as a result of the rapid increase of fossil fuel generation	Please refer to response to similar comment 15093	Government of France	Ministère de la Transition écologique et solidaire	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
28609	20	13	20	13	Suggest delete the word "research" as the folllowing 3 sentences contradict this as does the report cited	The word "research" has been deleted and the figures and text have been updated using the Global CCS Institute 2020 report	Tim Dixon	IEAGHG	United Kingdom (of Great Britain and Northern Ireland)
29415	20	13	20	15	The text states that CCS has "no immediate prospects for large-scale deployment". This seems misleading because in the following lines it is mentioned that there are several early-stage projects. Several of this are "large-scale". These projects can pave way for a broader CCS deployment.TS p50, line 25-27 states that "CCS is technologically ready, but remains in the demonstration stage and will always cost more than comparable processes in which CO2 is not captured and stored, necessitating strong policy support." As such, the prospects for broader deployment depend primarily on policy, which can be informed by this report. Several CCS-technologies have reached TRL9, but are not commersially mature (CRL).	Please refer to response to similar comment 15093	Government of Norway	Norwegian Environment Agency	Norway
51047	20	13	20	13	"to about 10% in 2019". This opens the way to erroneous interpretations if you do not indicate the reason why this decrease. Please add: "due to the rapid increase of fossil-fuel generation during the period"	Please refer to response to similar comment 14679.	Eric PROUST	European Nuclear Society (ENS)	France
51323	20	13	20	13	I believe that the actual Line 13 should be removed, and this one should be added in the same place: More than gas capture, the CCS process has also the transport and storage part. However, storage still needs to be studied better. Not focused only in capture, the whole process needs more research and testing investment. Most of the investment comes from the private sector and, in some places, from the government. However, there is a legal risk, because in many countries there are no consistent laws and rules for such action.	The figures and text have been updated using the Global CCS Institute 2020 report. A detailed discussion on CCUS is covered in subsection 6.4.2.5	Government of Brazil	Ministry of Foreign Affairs of Brazil	Brazil

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
64835	20	13	20	14	The sentence “Carbon capture and storage (CCS) remains largely in the research and demonstration phase without a meaningful impact on global CO2 emissions and no immediate prospects for large-scale deployment” is misleading, unsupported and wrong because it implies that CCS is an immature technology and therefore has no chance to be deployed when in fact this is not the case. The research is only for optimization, not because it is not a viable technology. See Cook, P. J. (2017). CCS research development and deployment in a clean energy future: Lessons from Australia over the past two decades. Engineering, 3(4), 477-484. “a great deal is now known about CCS through research, demonstration, and deployment. We know how to do it; we are confident it can be done safely and effectively; we know what it costs; and we know that costs are decreasing and will continue to do so.” Also the statement “no immediate prospects for large-scale deployment” is misleading given the following sentence that says “There are now a number of ongoing and upcoming CCS projects (51 in 2019) with a capacity of 40 MtCO2yr-1f rom operation and in-construction plants. Further, the plants under early and advanced stages of development in 2019 could provide additional capacity of around 60 MtCO2yr-1(Global CCS Institute 2019)” Thus the sentence “Carbon capture and storage (CCS) remains largely in the research and demonstration phase without a meaningful impact on global CO2emissions and no immediate prospects for large-scale deployment” should be replaced by “CCS is a proven technology for safe a long-term disposal of CO2 (Cook, 2017), with increasing prospects for large scale deployment. There are now a number of ongoing....”	The figures and text have been updated using the Global CCS Institute 2020 report. A detailed discussion on CCUS is covered in subsection 6.4.2.5	Katherine Romanak	The Univeristy of Texas at Austin	United States of America
79573	20	13	20	19	The section on ccs should be displaced at the end of the § to have first all production technology, and be coherent with intro.	Suggestion accepted and text modified accordingly	Marc Daras	CentraleSupelecAlumni	France
17485	20	14	20	19	Perhaps relate the CCS capacity to annual emissions figures from Ch2 SOD, e.g. 40MtCO2 yr-1 of CCS capacity and annual emissions in 2018 is 38GtCO2 from FFI, therefore ~0.1% capacity. If one can make such claim scientifically noting FFI. Also, I recognise that the CCS capacity figure is 2019, while the CO2 FFI figure is 2018, however this might be updated before FGD. Thanks.	We have now updated the CCS figures using the Global CCS Institute 2020 report. The updated text is: "At present there are 28 commercially operating CCS facilities accounting for a CO2 removal capacity of 40 million tonnes per year. In addition, 37 commercial projects are in various stages of development and construction (Global CCS Institute, 2020)"	Alaa Al Khourdajie	IPCC	United Kingdom (of Great Britain and Northern Ireland)
17487	20	15	20	17	Is the 40MtCO2 yr-1 mentioned in line 17 difference from the one mentioned in line 15? Hence with "an additional" capacity?	Please refer to response to similar comment 17485	Alaa Al Khourdajie	IPCC	United Kingdom (of Great Britain and Northern Ireland)
17839	20	15	20	15	"no immediate prospects for large-scale deployment" is incorrect. Three large-scale, commercial CCS facilities are under construction; 13 are in advanced development reaching front end engineering design (FEED) Reference: Global Status of CCS Report 2020 globalccsinstitute.com/resources/global-status-report/	Please refer to response to similar comment 15093	Eve Tamme	Global CCS Institute	Belgium
17841	20	15	20	15	26 commercial facilities are now operating: Reference: Global Status of CCS Report 2020 globalccsinstitute.com/resources/global-status-report/	Please refer to response to similar comment 15093	Eve Tamme	Global CCS Institute	Belgium
877	20	16		17	some ongoing ...projects	Please refer to response to similar comment 15093	Alok Dhaundiyal	Szent Istvan University	Hungary
17843	20	17	20	17	65 in 2020 ongoing and upcoming CCS projects. Reference: Global Status of CCS Report 2020 globalccsinstitute.com/resources/global-status-report/	Please refer to response to similar comment 15093	Eve Tamme	Global CCS Institute	Belgium

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
17845	20	19	20	19	72 MtCO2 yr-1 in additional capacity Reference: Global Status of CCS Report 2020 globalccsinstitute.com/resources/global-status-report/	Please refer to response to similar comment 15093	Eve Tamme	Global CCS Institute	Belgium
78039	20	19	20	19	Suggested edit: Suggested edit: At the end of the sentence insert sentence: "Pilot plants for carbon negative natural gas based electric power generation with Direct Air Capture (DAC) at the KtCO2/Yr level have been operating in the US and commercial scale implementation of this technology is being planned (Soltof 2019) (Exxon 2020)." Rationale: see references. References: Exxon 2020. ExxonMobil expands agreement with Global Thermostat, sees promise in direct air capture technologySoltoff, Newsroom Sept. 21. Soltoff, Ben. 2019. Inside ExxonMobil's hookup with carbon removal venture Global Thermostat. GreenBiz August 29.	This subsection covers the recent trends but a detailed discussion on future prospects and projections for CCUS are covered in subsection 6.4.2.5	Ron Baiman	Benedictine University	United States of America
17483	20	20	20	20	terawatt-hours could be mentioned earlier in the section as it is used above.	The text has been updated as suggested	Alaa Al Khourdajie	IPCC	United Kingdom (of Great Britain and Northern Ireland)
879	20	21			another half	The sentence was rewritten after updating the data	Alok Dhaundiyal	Szent Istvan University	Hungary
2329	20	21	20	26	says following "Geothermal for electricity generation is concentrated in a limited number of courtries and the prospects for large-scale development in the next decade are relatively limited, based on current scenario". It is only a view based on current plants - there is in fact a lot of scale up potential if governments acted. So i propose to change the sentence to something like: "Geothermal for electricity generation is concentrated in a limited number of courtries and the prospects for large-scale evelopment in the next decade are relatively limited, based on the limited ambition outlined in government plans."	The text has been updated as suggested	Nicholas Wagner	International Renewable Energy Agency (IRENA)	Germany
2331	20	21	20	26	I think a time horizon qualification is necessary here, so I'd suggest the following: "The share of marine energy in the electricity mix has doubled since 2010 but remains very low (1 TWh in 2018) to make any substantial impact towards low-carbon energy transitions in the near-term (IRENA 2020a; IRENA 2020b) (See section 6.4.2.9)."	Noted. The figures and text were updated using latest available reports.	Nicholas Wagner	International Renewable Energy Agency (IRENA)	Germany
30711	20	27	20	27	In paragraph 6.3.7, it is only mentioned about the lowering cost of batteries, however the issue about the laterality of the geograhpical locations to access to rare earth should be should be mentioned.	Accepted and incorporated in the text.	Government of Japan	Climate Change Division - Ministry of Foreign Affairs	Japan
37673	20	27	20	27	In this section, there is no mention of safety issues associated with battery storage. As regulations are developed with regard to safety issues, cost of batteries including insurance costs will rise. While this issue is covered in brief later, it should be mentioned here as well.	Noted. The issue of safety is mentioned in the text with the example of Korea.	Ravi B Grover	Homi Bhabha National Institute	India
77361	20	27	21	9	Suggest to add date on the by far largest source of electricity storage in the grid: pumped hydro storage	Accepted. The year is now mentioned in the modified text	Atle Harby	SINTEF Energy Research	Norway
55639	20	30	20	30	Regarding the use of "intermittent", the proper term is “variable” and should be used throughout this report.	Accepted and changed made where applicable	Government of United States of America	U.S. Department of State	United States of America
881	20	31			the flexiblity	Noted and edited during text revision	Alok Dhaundiyal	Szent Istvan University	Hungary

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
37101	20	31	20	44	Trillions of units of power have to be stored by Li-ion batteries if solar PVs have to be the main drivers.	(Combined response to comments 37101, 37103, 37105, 37107, 37109, 37111, 37113, 37115, 37117) Noted. The issue of mineral mining with respect to battery, Evs and renewable technologies has been included in the text now	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37103	20	31	20	44	This will increase the demand for Lithium Ion based storage devices. This has its own concerns because of	Please refer to response to comment 37101	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37105	20	31	20	44	issues like large demand for Lithium mining and production, waste generation, reprocessing costs apart	Please refer to response to comment 37101	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37107	20	31	20	44	from environmental issues. These numbers have to be figured out. Apart from this, the production	Please refer to response to comment 37101	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37109	20	31	20	44	process of PV panels is energy intensive, for example it takes around 5 years of operation of the solar	Please refer to response to comment 37101	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37111	20	31	20	44	power plant to generate the same amount of energy that is used to produce the PV system; moreover, a	Please refer to response to comment 37101	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37113	20	31	20	44	joint report by the International Renewable Energy Agency (IRENA) and the International Energy Agency	Please refer to response to comment 37101	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37115	20	31	20	44	Photovoltaic Power Systems Programme (IEA-PVPS) projected that solar waste would reach at least 78	Please refer to response to comment 37101	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37117	20	31	20	44	million tonnes by 2050.	Please refer to response to comment 37101	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
43555	20	31	20	31	Replace "element in" with "factor of"	Noted and edited during text revision	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy
43865	20	31	20	32	Intermittency has always been the biggest hurdle of achieving 100% (and baseload) renewably-sourced elctricity. This inherent intermittency, however, can be addressed through efficient energy storage and battery technologies. In Ziegler et al. (2019), baseload RE electricity requires energy storage capacity at a rate lower than $20/kWh [11].	Noted. The issue of intermittency is covered in detail in subsections 6.4.3 and 6.4.4	Vince Davidson Pacañot	University of the Philippines Diliman	Philippines
74867	20	31	20	44	As a matter of urgency battery storage for system flexibility needs to be incorporated both now and together with future intermittent renewable energy plants	Noted	Government of Kenya	Kenya Meteorological Service	Kenya
76393	20	31	20	44	The discussion around batteries fails to discriminate between the provision of grid stabilisation and energy transfer. So far batteries are limited to fixing the inherent grid instabilities caused by wind and solar. They are in effect a "bandaid" on an existing problem amd make a lot of money out of supplying this service. Thrue energy storage and temporal transfer is not happening and this section should be claerr about that.	Noted. This subsection focuses on battery storage as it is one of key trends in evolution of energy systems in past five years. More detailed discussion on system integration of RE, grid stabilization and energy sotrage is covered in subsections 6.4.3 and 6.4.4	Robert Parker	Nuclear for Climate Australia	Australia

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
77331	20	31	20	44	I think it is important to include information about the limited volume of energy grid-connected batteries can provide. They may have a large capacity in power (MW), but after one hour or two,the energy capacity (MWh) is used. On average, battery storage can provide 17GWh/8GW = 2,1 hours. This can help solving some of the rapid short-term fluctuations in variable renewable generation (VRE) from wind and solar power, but not the variation over longer time frames (hours and days, very likely to create huge challenges for weather-driven generation as wind and solar. Weather patterns typically change after several days, leaving for instance a large region with almost no wind for several days.	Noted. We have covered the recent trends in battery stroage systems in this subsection. Subsection 6.4.4 covers details of batteries and other energy storage technologies along with their limitations	Atle Harby	SINTEF Energy Research	Norway
77221	20	32	20	33	The sentence anticipates "capacity" data will be provided, but power is instead referenced. The two should be aligned, or better clarified and specific meaning of capacity in this context.	Accepted. The text has been modified for better clarity.	Giacomo Grasso	ENEA	Italy
77333	20	34	20	34	suggest to add "for about two hours storage or generation" after "....battery storage deployment was 8 GW (17 GWh)"	Noted. This sentence has been removed during text revision	Atle Harby	SINTEF Energy Research	Norway
883	20	36			fell (stick to one standard) or use 'reduced by'	Noted and edited during text revision	Alok Dhaundiyal	Szent Istvan University	Hungary
7855	20	36	20	36	page 54 line 34 has the value 97% for the amount of storage that is pumped storage (rather than the 96% mentioned on this page) Page 54 also has a reference	Noted. The text has been revised to "over 90%" based on the latest IEA World Energy Outlook report in 2020	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
10063	20	36		36	Are there any estimation on when battery cost for grid/power plant purpose will be low enough to encourage use of intermittent renewable energy?	The future projections are discussed in subsection 6.4.4	Government of Indonesia	Ministry of Environment and Forestry	Indonesia
9809	20	37	20	38	please add reference	Noted. This text was revised and reference added where applicable	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
85777	20	37	20	37	Suggest update: The capacity figure is incorrect. Initial capacity: 100MW, 129MWh. The battery size has now been increased and capacity is 150 MW (193.5 MWh) - references: Neoen, 2021, accessed 4 February 2021 https://hornsdalepowerreserve.com.au/; ARENA, 2020. South Australian battery grows bigger and better. Accessed on 4 February 2021 <https://arena.gov.au/blog/south-australian-battery-grows-bigger-and-better/>.	Accepted and updated in text	Government of Australia	Department of Industry, Science, Energy and Resources	Australia
20899	20	38	20	38	About "[...] in Japan.", we suggest to add: which amounts to a few seconds of the respective national demand.	Noted. The text was deleted during revision. Large scale utility projections (>100 MW) are mentioned as examples in the text now	Government of France	Ministère de la Transition écologique et solidaire	France
51053	20	38	20	40	"Future project announcements include comprehensive renewable-plus-solar projects like the 400 MW (800 MWh) solar plus storage project in California to replace retiring gas plants (Roy et al. 2020)" The reference is incorrect: there is no mention of this 400 MW (800 MWh) project in the referenced article by Roy et al.	Noted. The text was updated during revision and reference has been updated	Eric PROUST	European Nuclear Society (ENS)	France
71545	20	38	20	38	is newer information available? 2018 is already two years ago.	Noted. Information has been updated where recent data was available	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
4109	20	39	20	39	"renewable-plus-solar projects" does not make sense as solar is a sort of renewables.	Noted and corrected in revised text	Tatsuki Ueda	National Agriculture and Food Research Organization	Japan
62115	20	39	20	39	Here would be a good opportunity to refer to the Cerro Dominador (Chile, 2021) and Noor Energy 1 (Dubai, 2022) CSP projects, which includes 1750 MWh (Cerro Dominador) and 8100MWh (Noor Energy 1) of storage and, making it 15 and 63 times larger than the Horsedale battery in Australia you mention. For reference see for example: Schöniger et al 2021 https://doi.org/10.1080/15567249.2020.1843565	Noted. Due to space constraints, this subsection is limited to recent trends in battery storage but other storage technologies are discussed in detail in subsection 6.4.4.	richard thonig	IASS Potsdam	Germany
9571	20	40	20	40	delete ")" after "2020)"	Noted and edited during revision of the text	Jaume Gasia	Jose Antonio Romero Polo SA	Spain
51055	20	40	20	41	"the solar-plus-storage tenders for round the clock electricity supply in India (Burke and Do, 2020)" This should be deleted: it is erroneous and misleading. Indeed, 1/ The referenced article by Bruke and Do does not provide any indication as to the storage technology (it fact, it does not even say it is for round-the-clock supply, it just says "for both off-peak and peak times but right, there has been an auction by SECI on round-the-clock supply en early 2020) 2/ In fact, according to [1], the call for tenders by SECI for round-the-clock supply specified that "the energy storage system, if any, can be based on battery, mechanical, pumped or any other technology". 3/ according to [1], the call for tender specified that the goal was "setting up an aggregate 400 MW capacity of ISTS-connected renewable [solar or wind!] power projects anywhere in India", which offered the possibility for the bidders to combine wind and solar generation and spread the solar generation facilities all over the country to minimize electricity storage needs. And anyway, there is no indication of the minimum power that is required to be supplied round-the-clock. [1] https://www.pv-magazine-india.com/2019/10/18/seci-tenders-400-mw-of-hybrid-solar-with-storage-option/	Accepted. Text revised using updated information and references	Eric PROUST	European Nuclear Society (ENS)	France
885	20	43			other technology-related concerns	Noted and edited during revision of the text	Alok Dhaundiyal	Szent Istvan University	Hungary
63153	20	43			need a comma after "Korea"	Noted and edited during revision of the text	Jennifer Sklarew	George Mason University	United States of America
887	21	1			use hyphen 'low-cost'	Noted and edited during revision of the text	Alok Dhaundiyal	Szent Istvan University	Hungary
9811	21	1	21	1	write electric vehicle instead of EV in the first mention	Accepted and included in revised text	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
71547	21	1	21	2	The phrase is not logical: Why does a higher battery capacity increase the demand for low cost technologies? It contributes rather to lowering the costs.	Accpeted. This has been removed from the text now	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
77223	21	1	21	1	"per year" should be removed, not only because it does not match with the capacity concept, but also because has little sense in a sentence introducing a reached value (which refers to a specific moment, not a period).	Accepted and updated in text	Giacomo Grasso	ENEA	Italy

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
81057	21	1	21	1	Stating that the overall volume of battery manufacturing raised the demand for EVs is somewhat conflating cause and effect. Demand for low cost Evs was in fact one of the drivers for the large increase in battery manufacturing, and this increased scales has also led to decreased costs (through economies of scale, technological learning curves, etc.).	Accpeted. This has been removed from the text now	Aaron Barkhouse	SunPower Corporation	United States of America
71549	21	4	21	4	Are there really more charging stations than cars?	Noted and corrected. The number of chargers were 1.3 million in 2020	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
7857	21	6	21	6	The cost of battery packs has also decreased to USD 56/kWh in 2019 -- this value seems too low to be valid. Looks like this should be USD 156/kWh (https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/as-battery-costs-plummet-lithium-ion-innovation-hits-limits-experts-say-58613238)	Accepted and updated in text using the latest data from BNEF (USD 137/kWh in 2020)	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
28503	21	6	21	7	The cost of battery packs has also decreased to USD 156/kWh in 2019, not 56. This is a major mistake. More broadly, this is about an average cost, and not a single value. There is a lot more to say about this, how costs vary base don scale of production facilities and chemistries, as well as cost of materials.	Please refer to response to similar comment 7857	Pierpaolo Cazzola	International Transport Forum	France
47105	21	6	31	7	Chapter 6, page 21, line 6-7: "The cost of battery packs has also decreased to USD 56/kWh in 2019, a drop of 85% since 2010 (see Section 6.4)." While section 6.4 is cited, the USD 56/kWh in 2019 is not found in section 6.4. Instead, battery price mentioned in Section 6.4, page 55, Table 6.5 suggests that Li-Ion Battery (LIB) stat of art price is at USD $176/kWh in 2017 (more about this citation in the next comment). There is no citation or data to support that LIB pack cost is "USD 56/kWh in 2019, a drop of 85% since 2010," and $56/kWh is less than half of available data on LIB battery cost https://bit.ly/ipcc_review_wg3_figs Review Visual 4. This sentence needs to be corrected or removed.	Please refer to response to similar comment 7857	Kenneth Laberteaux	Toyota Motor North America-R&D	United States of America
889	21	7			in the case…	Noted. The text was removed during revision	Alok Dhaundiyal	Szent Istvan University	Hungary
891	21	9			chapter (lower case)	Noted. The text was removed during revision	Alok Dhaundiyal	Szent Istvan University	Hungary
85339	21	9	21	9	this paragraph should also alude to new advances in hydrogen for heavy transport where batteries are too heavy and to hydrogen fuel cells as potantially more sustainable in terms of circular economy as lithium batteries depend on mining and rare earths which poses additional sustainability and supply chain/human rights issues.	Noted. Due to space constraints, this subsection is limited to recent trends in battery storage but other storage technologies are discussed in detail in subsection 6.4.4.	Linda Hancock	Deakin University	Australia
28405	21	10	22	23	Missing points about Carbon border adjustment mechanism and break through offshore wind parks without subsidies or contract for difference and strike price Source: Condon, Madison and Ignaciuk, Ada, Border Carbon Adjustment and International Trade: A Literature Review (2013). OECD Working Paper No. 6, Available at SSRN: https://ssrn.com/abstract=2693236 or http://dx.doi.org/10.2139/ssrn.2693236	Taken into account - combined with other comments on carbon leakage; subsidy free renewable developments added	Naud Loomans	Eindhoven University of Technology	Netherlands

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
28505	21	10	23	28	This section (in particular the parts on carbon pricing) do not even mention low carbon fuel standards. This is a serious omission that deserves being fixed. Some useful references on this include: https://www.sciencedirect.com/science/article/pii/S0301421516303901, https://www.sciencedirect.com/science/article/pii/S0739885915000530, plus California's LCFS web site: https://ww2.arb.ca.gov/our-work/programs/low-carbon-fuel-standard Far more could also be said here on the use of regulatory approaches (e.g. standards for energy efficiency).	Rejected - outside of the scope of the chapter (topic for transport chapter); removed from earlier draft due to space constraints	Pierpaolo Cazzola	International Transport Forum	France
30713	21	10	22	23	Carbon pricing, such as emissions trading and carbon taxes, affect the energy system, but they are essentially a part of climate policy and need not to be dealt with in this chapter as they are dealt with in other chapters. Rather, the removal of fossil fuel subsidies is an energy policy that contributes to climate change mitigation and should be addressed in this section.	Taken into account - energy subsidies and in particular fossil fuel subsidies have a dedicated box; carbon pricing is important for energy sector as economy-wide instrument and hence discussed	Government of Japan	Climate Change Division - Ministry of Foreign Affairs	Japan
71551	21	10	23	12	The discussion of energy policies seems quite incomplete. Policies for heating and cooling, energy efficiency or hydrogen are not mentioned at all. The discussion on RES support in the electricity sector is one-sided as well as the discussion on carbon prices. The examples for energy transitions in Indonesia and India (while very important) take a very prominent role in the section. In my opinion, the section should be restructured and additional contents included while the presented contents could be partly shortened.	Taken into account - energy efficiency measures mentioned in the text; detailed discussion on policies and policy mixes in transport, heating etc. should be found in the respective chapters on end-use sectors	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
74187	21	10	23	26	This section should include references to the government support for the development of new nuclear, CCS, hydrogen and other clean energy technologies. https://www.nei.org/news/2020/congress-historic-funding-carbon-free-nuclear	Taken into account - list on low-carbon technologies is not exhaustive; for further detailed information on technologies see respective technology sections in this chapter	Jeffrey Merrifield	Pillsbury Law Firm	United States of America
85437	21	10	23	26	"The energy policy landscape continues to evolve" does not give a clear idea what the paragraph is about. A "policy landscape" can mean almost anything, and of course it continues to evolve. I would go for something like "Carbon pricing, energy subsidies, and other energy policies" Then I would replace line 11-44 - that I experience as meaningless and offputting word salad - with a clear message of what people can expect. E.g. "The role of carbon pricing - once thought the most important policy instrument - is small but growing. Energy subsidies could play an important role in accelerating the transition, especially if fossil fuel subsidies - that still represent more than half of all energy subsidies - would be reduced. Other policy instruments include ...." I would also restructure the paragraph in that order (carbon pricing, energy subsidies, the rest) and turn the box on energy subsidies into regular text.	Noted	Auke Hoekstra	Eindhoven University of Technology	Netherlands
85487	21	10	22	23	A policy instrument that should be added here I think is a way to price price carbon at the border (carbon border adjustment mechanism) E.g. doi 10.2139/ssrn.2693236	Taken into account - mentioned carbon border adjustment mechanism, but added peer-reviewed reference instead of the suggested one	Auke Hoekstra	Eindhoven University of Technology	Netherlands
79575	21	11			Since there are différent energy policy, such as policies on standarts or grid access… the first sentence could read: "The current policy landscape in the energy sector for climate remediation aims at reducing carbon intensity / energy efficiency and renewable energy deploiement. It consists...". Furthermore, at the end a sentence could be added such as " These policies inluence the energy supply sector on subsidies to specific production, and through the demand side."	Noted - existing energy policies / policy mixes may target multiple goals	Marc Daras	CentraleSupelecAlumni	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
71553	21	12	21	14	The phrase is very judgemental. I suggest to: - rather than being constructed in a consistent manner, - an include many sectoral but also some economy-wide instruments such as ...	Accepted - text revised	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
27717	21	14	21	14	Delete "comprehensive".	Accepted - text revised	Eleni Kaditi	Organization of the Petroleum Exporting Countries, OPEC	Austria
43867	21	15	21	37	Developing countries may have a different perspective as to how they craft their policies. A case to look at is in the Philippines, where its energy bureau allowed 100% foreign ownership of geothermal energy projects [12]. Hence, policy instruments regarding investment ownerships should also be mentioned in this section, other than FiT, RPS, and such.	Taken into account - part of non-exhaustive list on governmental support	Vince Davidson Pacañot	University of the Philippines Diliman	Philippines
71555	21	15	21	27	The paragraph could be shortened: - one phrase on institutional capacity determining the policy choice. One phrase on FIT and market-based instruments: Suggestion: More administrative instruments (such as FIT) or more market-based instruments (such as auctions) might be suitable for different degrees of technology development but the instrumental choice also depends on factors such as the organisation of electricity market, the overall investment climate or institutional capacities. The effectiveness of instruments as well as the costs of support are mainly influenced by the specific design of the instruments and do not so much depend on the instrument choice.	Taken into account - text shortened; statement on the importance of instrument implementation added	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
73945	21	15	21	37	The instruments described are mostly focused on large-scale renewable technologies. Something should be said about new regulatory and policy instruments for distribution level or behind-the-meter renewables (e.g. electricity rates, net metering and solar compensation mechanisms, etc.)	Noted - discussion of suggested instruments is left out due to space constraints	Heleno Miguel	Lawrence Berkeley National Laboratory	United States of America
893	21	17			comma after 'et al.' is required	Editorial. Noted	Alok Dhaundiyal	Szent Istvan University	Hungary
895	21	23			Stick to the standard English (favour) (check thorougly)	Editorial. Noted	Alok Dhaundiyal	Szent Istvan University	Hungary
43557	21	25	22	26	In this Box a brief discussion of cost-effectiveness of measures is missing. Moreover, subsied are widely used not only to support specifc fuels of energy-using technologies, but also to support energy efficiency uptakes.	Taken into account - energy efficiency measures are mentioned	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy
10065	21	27		29	FIT policies effectiveness in relation with country specific contexts (e.g. economic growth, power sector subsidies, domestic renewable energy technology capacity, etc.) should be explored.	Taken into account - more detailed discussion not possible due to space constraints	Government of Indonesia	Ministry of Environment and Forestry	Indonesia
20901	21	27	21	31	This requires some explainations. This is certainly not a general result in environmnetal economics.	Rejected - no reference is provided	Government of France	Ministère de la Transition écologique et solidaire	France
52163	21	28	21	28	"their effects" is not defined.	Accepted - text revised	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
897	21	32			remove comma after (RPS)	Accepted - text revised	Alok Dhaundiyal	Szent Istvan University	Hungary

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
30715	21	36	21	36	From rhetoric point of view, "Besides high effectiveness" should be changed to "Despite high effectiveness".	Noted - text changed	Government of Japan	Climate Change Division - Ministry of Foreign Affairs	Japan
71557	21	36	21	37	While this is true it depends on the quality of policy making: I would add to the sentence: especially when technology costs are high or tariffs do not decline in line with technology costs.	Taken into account - added "potentially" high program cost	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
28943	21	37	21	37	Please add, for completeness: "Likewise, incentive schemes that foster the adoption of other energy technologies such as efficient heating appliances or electric vehicles, among others, have been developed" (Refer to: Bjerkan et al.(2016):Incentives for promoting Battery Electric Vehicle (BEV) adoption in Norway; Snape et al.2015: Will domestic consumers take up the renewable heat incentive? An analysis of the barriers to heat pump adoption using agent-based modelling)	Taken into account - combined with other comments on policies in buildings and transport	Fabian Heymann	INESC TEC	Switzerland
8407	21	38	22	2	There is no scientific way of recognizing carbon price - hence carbon tax or ETS cannot be effectively implemented. One possible course of action is to develop an equitable carbon pricing systems as :- Firstly, it is proposed that scientists and economists must work together to determine a Standard Carbon Price (SCP) based on the world's assimilative capacity of CO2. This SCP will be applicable across all economies but differentiated according to the GDP at different stages of development. As an example, if price per ton of CO2 is set at USD100, this full cost will be borne by countries with per capita GDP of say over USD30,000. For countries with a per capita GDP of USD3,000, the consumers in these economies would only pay for USD10 per ton of CO2. Secondly, the carbon content of products and services must be estimated and consumers should pay for the price of their embedded carbon content.	Noted - beyond the scope of this chapter (topic could be discussed in policy chapter)	Otto Poon	President, Hong Kong Academy of Engineering Sciences.	China
8409	21	38	22	2	Thirdly, the cost of carbon should be paid for when goods and services are purchased now and not be passed to future generations. Fourthly, carbon costs are built into the products and services and paid for by the consumers at a SCP of the consumer's country and not that of the producing country. Fifthly, the SCP should be reviewed and determined annually depending on the difference of total carbon emission and the assimilative capacity of the earth.	Noted - beyond the scope of this chapter (topic could be discussed in policy chapter)	Otto Poon	President, Hong Kong Academy of Engineering Sciences.	China
18219	21	38	22	2	(Section 6.3.8) This para could be clearer. For e.g. "different measures have been suggested.." - which measures? - "studies indicate prices need to be higher…" - how high / how much higher? - "consistent with this suggested range" - what range? - "the impact...is sizeable" - unclear what impact is being referenced; why it's sizeable; and according to what measure. The France and Germany examples in this para are somewhat vague - it would perhaps be helpful to expand them in a little more detail.	Taken into account - combined with other comments on carbon price ranges	Government of United Kingdom (of Great Britain and Northern Ireland)	Department for Business, Energy & Industrial Strategy	United Kingdom (of Great Britain and Northern Ireland)
71559	21	38	22	2	The paragraph on carbon pricing misses the other side of the picture. It is also discussed that carbon prices are not a sufficient instruments for decarbonizing the economy, especially carbon prices that do not differentiate between sectors. The discussion should be included.	Taken into account - detailed discussion is not possible due to space constraints; regional- and sectoral-specific policies mentioned in the text	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
69479	21	40	21	42	Please be somewhat more explicit: the type of measures most often suggested to improve the performance of the ETS and other carbon pricing schemes are of the "price caps and price floors" type, under different names. Modelling has suggested that tighter targets with price caps and price floors could be tailored to get the same expected emission results at much lower expected mitigation costs (Philibert, C. 2009, Assessing the value of price caps and floors, Climate Policy 9: 612-633.	Accepted - text revised	Cédric PHILIBERT	Institut Français des Relations Internationales	France
10917	21	45	21	48	please include the suggested range of carbon price to meet the Paris goals as xxxxx, which be cited from Stiglitz and Stern 2017. Also include the the range of carbon price to meet the Paris Agreement goal from World Bsnk report	Accepted - text revised, range from Stiglitz and Stern added	Dong-Woon NOH	Korea Energy Economics Institute	Republic of Korea
10919	21	45	21	45	please include the factors or reasons for the low(5%) share of emissions covered are consistent with the suggested range of carbon price at the end of the phrase.(for example, differences in the stringency of climate regulation(page 22) in short)	Accepted - text revised, range from Stiglitz and Stern added	Dong-Woon NOH	Korea Energy Economics Institute	Republic of Korea
16341	21	45	21	48	please include the suggested range of carbon price to meet the Paris goals as xxxxx, which be cited from Stiglitz and Stern 2017. Also include the the range of carbon price to meet the Paris Agreement goal from World Bsnk report	Accepted - text revised, range from Stiglitz and Stern added	Government of Republic of Korea	Korea Meteorological Administration (KMA)	Republic of Korea
16343	21	45	21	45	please include the factors or reasons for the low(5%) share of emissions covered are consistent with the suggested range of carbon price at the end of the phrase.(for example, differences in the stringency of climate regulation(page 22) in short)	Accepted - text revised, range from Stiglitz and Stern added	Government of Republic of Korea	Korea Meteorological Administration (KMA)	Republic of Korea
30717	21	45	21	46	Stiglitz, Stern 2017 recommends the carbon price alligned with the paris agreement as below and these numbers should be included. == Commission concludes that the explicit carbon-price level consistent with achieving the Paris temperature target is at least US\$40–80/tCO2 by 2020 and US\$50–100/tCO2 by 2030, provided a supportive policy environment is in place.	Accepted - text revised, range from Stiglitz and Stern added	Government of Japan	Climate Change Division - Ministry of Foreign Affairs	Japan
72129	21	45	21	46	The following reference supports the statement in that sentence. The reference uses a global CO2 constraint and determines the necessary CO2 price for different decarbonization levels, obtaining prices significantly higher than 10 $/ton CO2. M. Victoria, K. Zhu, T. Brown, G. B. Andresen, M. Greiner, Early decarbonisation of the European energy system pays off, Nature communications 11, 6223 (2020) https://www.nature.com/articles/s41467-020-20015-4	Taken into account - text revised, range from Stiglitz and Stern added	Marta Victoria	Aarhus University	Denmark
79577	21	46			Together with Stiglitz and Stern study, the following study could be referenced: Alain Quinet et al., La valeur de l'action pour le climat. Février 2019, which give values of carbon for remediation following a net zero trajectory to 2050.	Taken into account - text revised, range from Stiglitz and Stern added	Marc Daras	CentraleSupelecAlumni	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
60451	21	48	22	2	CCU technologies are typical examples of technologies that are highly depending on the carbon pricing on their inclusion in ETS systems. Cleare and more comprehensive description and comptability between emitter and utilisator of CO2 has to be defined to consider ther effort of CO2 emission avoidance, especially in the context of industrial symbiosis. To allow for the deployment of CCU technologies, EU ETS has to consider both values of CCU : temporal storage of CO2 but also CO2 emission avoidance by substitution! (position paper on the inclusion of CCU in EU-ETS: https://www.co2value.eu/wp-content/uploads/2020/06/CVE-paper-on-CCU-in-ETS-Recommendations-for-the-revision-of-the-Monitoring-and-Reporting-Regulation-MRR.pdf) •Hepburn et al., 2019, Nature, 575, 87-97.•SAM, 2018: Novel carbon capture and utilisation technologies, Scientific Advice Mechanism (SAM), Independent scientific advice for policy making. •SAPEA, 2018, Science Advice for Policy by EU Academies, Novel Carbon Capture and Utilisation Technologies-Research and Climate Aspects, Evidence Review Report, 2.	Rejected - outside of the scope of this section / chapter (does not only relate to the energy sector); see technology sections	Célia Sapart	Université Libre de Bruxelles / CO2 Value Europe	Belgium
76311	21	48	22	2	CCU technologies are highly depending on the carbon pricing on their inclusion in ETS systems. Clear and comprehensive description and comptability between emitter and utilisator of CO2 has to be defined to consider ther effort of CO2 emission avoidance, especially in the context of industrial symbiosis. To allow for the deployment of CCU technologies, EU ETS has to consider both values of CCU : temporal storage of CO2 but also CO2 emission avoidance by substitution! (position paper on the inclusion of CCU in EU-ETS: https://www.co2value.eu/wp-content/uploads/2020/06/CVE-paper-on-CCU-in-ETS-Recommendations-for-the-revision-of-the-Monitoring-and-Reporting-Regulation-MRR.pdf) •Hepburn et al., 2019, Nature, 575, 87-97.•SAM, 2018: Novel carbon capture and utilisation technologies, Scientific Advice Mechanism (SAM), Independent scientific advice for policy making.•SAPEA, 2018, Science Advice for Policy by EU Academies, Novel Carbon Capture and Utilisation Technologies-Research and Climate Aspects, Evidence Review Report, 2.	Rejected - outside of the scope of this section / chapter (does not only relate to the energy sector); see technology sections	Deepak PANT	Flemish Institute for Technological Research (VITO)	Belgium
83695	21	48	22	2	CCU technologies are typical examples of technologies that are highly depending on the carbon pricing on their inclusion in ETS systems. Cleare and more comprehensive description and comptability between emitter and utilisator of CO2 has to be defined to consider ther effort of CO2 emission avoidance, especially in the context of industrial symbiosis. To allow for the deployment of CCU technologies, EU ETS has to consider both values of CCU : temporal storage of CO2 but also CO2 emission avoidance by substitution! •Hepburn et al., 2019, Nature, 575, 87-97.•SAM, 2018: Novel carbon capture and utilisation technologies, Scientific Advice Mechanism (SAM), Independent scientific advice for policy making. •SAPEA, 2018, Science Advice for Policy by EU Academies, Novel Carbon Capture and Utilisation Technologies-Research and Climate Aspects, Evidence Review Report, 2.	Rejected - outside of the scope of this section / chapter (does not only relate to the energy sector); see technology sections	Christian Breyer	LUT University	Finland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
78805	22	1	22	1	CCU are typical examples of technologies that are highly depending on the carbon pricing on their inclusion in ETS systems. Cleare and more comprehensive description and comptability between emitter and utilisator of CO2 has to be defined to consider ther effort of CO2 emission avoidance, especially in the context of industrial symbiosis. To allow for the deployment of CCU technologies, EU ETS has to consider both values of CCU : temporal storage of CO2 but also CO2 emission avoidance by substitution! (position paper on the inclusion of CCU in EU-ETS: https://www.co2value.eu/wp-content/uploads/2020/06/CVE-paper-on-CCU-in-ETS-Recommendations-for-the-revision-of-the-Monitoring-and-Reporting-Regulation-MRR.pdf) • Hepburn et al., 2019, Nature, 575, 87-97.• SAM, 2018: Novel carbon capture and utilisation technologies, Scientific Advice Mechanism (SAM), Independent scientific advice for policy making. • SAPEA, 2018, Science Advice for Policy by EU Academies, Novel Carbon Capture and Utilisation Technologies-Research and Climate Aspects, Evidence Review Report, 2.	Rejected - outside of the scope of this section / chapter (does not only relate to the energy sector); see technology sections	Sylvain Nizou	CEA	France
899	22	2			no need of 'from the manuf..'	Rejected - "from the manufacturing" is correct	Alok Dhaundiyal	Szent Istvan University	Hungary
27421	22	2	22	24	The ecosystem-based vs technological distinction is interested, and similar to distinctions often mentioned in current literature. And the combined cayegory makes sense too. But the categorisation is not clear at the detailed level. Why are OF in the combined category and not ecosystem-based? And why exactly are the geochemical ones in the engineering category? I don't propose that you change it necessarily - especially this late in the game, but please show your workings a little.	Rejected - outside of the scope of the chapter	Nils Markusson	Lancaster University	United Kingdom (of Great Britain and Northern Ireland)
913	22	6			crucial role in	Noted	Alok Dhaundiyal	Szent Istvan University	Hungary
901	22	10			remove little and use proper word. Preposition is missing 'a little'?	Accepted - text revised ("little evidence")	Alok Dhaundiyal	Szent Istvan University	Hungary
30719	22	10	22	10	It is written as if carbon leakage is not occuring, however this is due to the massive free allocation in EU-ETS, and as clearly stated by EU, EU is considering CBAM due to the risk of carbon leakage. Therefore, it should be rewritten as below. == While there is currently little indication of carbon leakage, the EU is considering carbon border adjustment measures to cope with carbon leakage risk caused by increasing mitigation cost	Taken into account - text revised; combined with other comments on carbon leakage	Government of Japan	Climate Change Division - Ministry of Foreign Affairs	Japan
55641	22	10	22	13	Is this statement referring to just the limited example of German manufacturing firms and power plants? Is this broadly representative or are there examples of carbon leakage elsewhere? This sections suggests that there MIGHT be carbon leakage, but follows up with a statement saying that little indication exists for carbon leakage, based on a specific and limited example.	Taken into account - combined with other comments on carbon leakage	Government of United States of America	U.S. Department of State	United States of America
17489	22	11	22	11	Typo? "Zaklan 2019; for the EU ETS)"	Editorial- noted	Alaa Al Khourdajie	IPCC	United Kingdom (of Great Britain and Northern Ireland)
10921	22	12	22	12	please add the Germeshausen(2020) to the reference. I can not see the reference	Accepted - reference added	Dong-Woon NOH	Korea Energy Economics Institute	Republic of Korea

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
16345	22	12	22	12	please add the Germeshausen(2020) to the reference. I can not see the reference	Accepted - reference added	Government of Republic of Korea	Korea Meteorological Administration (KMA)	Republic of Korea
18221	22	13	22	17	(Section 6.3.8) These two sentences are a little unclear / vague. For example, it is unclear whether they are describing a negative or positive interaction. Suggest rewording and adding a little more detail to make it easier for the reader to see the key point being made.	Noted - Interactions can be complex; thus, no detailed discussion of the mentioned examples due to space constraints; furthermore, see discussions in policy chapter	Government of United Kingdom (of Great Britain and Northern Ireland)	Department for Business, Energy & Industrial Strategy	United Kingdom (of Great Britain and Northern Ireland)
69481	22	17	22	17	In case you wanted to be more specific, Böhringer and Rosendhal in 2010 already argued that with an emission cap in place, additional green quotas decrease the emission allowance price and thereby "benefit the dirtiest generation technologies" in slowing the coal to gas shift that would deliver the same emission reductions (at a lower cost); however, developing new renewable resources (e.g. wind, solar and others) from a very narrow basis allows learning that will unlock their climate-change mitigation potential (Philibert, C., 2011, Interactions of Policies for Renewable Energy and Climate, IEA Working Paper).	Noted - no detailed discussion possible due to space constraints	Cédric PHILIBERT	Institut Français des Relations Internationales	France
43869	22	18	22	23	Look into incentivizing the development and/or production of low-carbon fuels such as biofuels for transportation. As noted in Le Quéré, decarbonizing the transport sector could play a huge role in the long-term, more effective climate change mitigation.	Rejected - beyond the scope of the chapter (see transport chapter)	Vince Davidson Pacañot	University of the Philippines Diliman	Philippines
903	22	19			This phrase is in between the sentence (use comma before and after) (as well as......)	Editorial. Noted	Alok Dhaundiyal	Szent Istvan University	Hungary
37675	22	20	22	23	There is no mention of nuclear in this sentence. The Government of India has been promoting development of nuclear power based on a closed fuel cycle, and has sanctioned setting up of several reactors (700 MW PHWRs) in fleet mode. (Please see Grover, R. B., and M. R. Srinivasan, 2020, “Vikram Sarabhai: His vision for the development of Atomic Energy in India”, Current Science, 118(8): 1191-1195.)	Taken into account - list of low carbon technologies is not exhaustive	Ravi B Grover	Homi Bhabha National Institute	India
905	22	22			improvement, revamping … etc (not upgradation)	Editorial. Noted	Alok Dhaundiyal	Szent Istvan University	Hungary
27719	22	25	22	47	Box 6.3 should refer to inefficienct fossil fuel subsidies that encourage wasteful consumption.	Taken into account - mentioned in text	Eleni Kaditi	Organization of the Petroleum Exporting Countries, OPEC	Austria
30721	22	25	23	26	There is only explanation about the subsidies of fossil fuel, but we think it the amount and trend of subsideis towards renewable energy should also be mentioned.	Accepted - subsidy amount added	Government of Japan	Climate Change Division - Ministry of Foreign Affairs	Japan
75021	22	26	22	28	Whereas the fossil fuel subsidies are still allowed and contributes to 50% of total subsidies there is limited subsides towards the development of renewable energy save for feed-in-tariff. Most coal power plants in Africa are facing strong criticism and others are suspended forexample the 900MW Lamu coal power plant.	Taken into account - combined with previous comment on renewable subsidies	Government of Kenya	Kenya Meteorological Service	Kenya
907	22	29		30	With reference to ? 'Energy subsidies ..' market level. Subsidies are provided according to the market. Add it.	Noted	Alok Dhaundiyal	Szent Istvan University	Hungary
909	22	37		38	correct the sentence "Fossil fuel subsidies were around double the amount of subsidies spent on renewables" subsidies are countable ' The amount spent on fossil fuel were double…….'	Accpepted - text revised	Alok Dhaundiyal	Szent Istvan University	Hungary

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
77159	22	37	22	38	This is an important statement and I wonder whether there is a better reference to substantiate it.	Accepted - reference was wrong	Carles Pelejero	Institut de Ciències del Mar, CSIC	Spain
79579	22	42			Only G20 countries are referenced for removing and reducing fossil fuel subsidies. One should reference other countries, and notably oil producing countries which were in e need of reducing the cost of such policies. Such reduction fas risen social turmoil beacuse impacting low to middle revenu classes. (Iran, Egypt, Saudi Arabia, Algeria...)	Noted	Marc Daras	CentraleSupelecAlumni	France
911	22	43			comma after (for example)	Editorial. Noted	Alok Dhaundiyal	Szent Istvan University	Hungary
55643	22	44	23	26	Given the small share of total fossil fuel subsidies going to LPG for cooking, and given that this is one of the few areas that fossil fuel use provides low-income groups benefits, particularly health benefits compared to cooking with traditional biomass stoves, it is a surprising choice to focus attention to this use of fossil fuel subsidies rather than the much larger fossil fuel subsidies that go towards transportation and electricity which more heavily benefit the rich. The LPG cooking case presented here would seem to be inappropriately putting a positive spin on the generally damaging and expensive use of fossil fuel subsidies. However, the use of LPG for cooking does provide benefits compared to the use of traditional biomass fuels and stoves. This perspective could be used in a box, but the high cost and damages of fossil fuel subsidies should be expanded well beyond the paragraph presented. See the discussion on cooking in, for example: "Energy in Developing Countries", Office of Technology Assessment, United States Congress, OTA-E-486, Government Printing Office, Washington, D.C. 1991, ~140 pp. Joy Dunkerley, Samuel F. Baldwin, Karen Larsen, Robin Roy, Paul S. Komor, Nina Goldman, Sharon Burke. http://www.princeton.edu/~ota/ http://fas.org/ota/otareports/ "Fueling Development: Energy Technologies for Developing Countries", Office of Technology Assessment, United States Congress, OTA-E-516, Government Printing Office, Washington, D.C. 1992, ~330 pp. Joy Dunkerley, Samuel F. Baldwin, Paul Komor, Sharon Burke. http://www.princeton.edu/~ota/ http://fas.org/ota/otareports/	Taken into account - text shortenend and qualifying statement added; examples have been selected in accordance with other chapters	Government of United States of America	U.S. Department of State	United States of America
55645	23	1	23	15	This section is meant to be an example of how some subsidies have proven to be regressive, but is unclear how the Indonesia example is regressive.	Rejected - no reference is provided	Government of United States of America	U.S. Department of State	United States of America
69467	23	1	23	15	One important driver of the success of the Kero Zero program has been the Kerosene withdrawal, leaving no choice to the population (see Pertamina and World LP Gas Association, n.d., Kerosene to LP Gas Conversion Programme in Indonesia, Jakarta and Paris.	Noted - relevant text paragraph is removed from the text due to space constraints	Cédric PHILIBERT	Institut Français des Relations Internationales	France
79581	23	1	23	26	The two examples are on the same policy. One on LPG should be enough, since the climate co benefit is small.	Noted - selection of examples in accordance with other chapters	Marc Daras	CentraleSupelecAlumni	France
9897	23	5	23	7	In this chapter, the kerosene subsidy used to convert kerosene to LPG as cooking fuel is used to explain the subsidy to reduce fossil fuel use in Indonesia, however, recently the implementation of biodiesel subsidy which implemented to reduce diesel fuel consumption is the successful subsidy policy in Indonesia. Suggestion: This policy can be explained in this chapter for explaining the subsidy use to reduce fuel consumption in Indonesia.	Noted - selection of examples in accordance with other chapters	Government of Indonesia	Ministry of Environment and Forestry	Indonesia

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
27425	23	11			Yoy may want to reference also these papers regarding the risk of obstructing emissions reduction efforts: 1) Quantifying the potential scale of mitigation deterrence from greenhouse gas removal techniques, McLaren, D. 2020, In: Climatic Change. doi.org/10.1007/s10584-020-02732-3, 2) Beyond "Net-Zero": A Case for Separate Targets for Emissions Reduction and Negative Emissions, McLaren, D., Tyfield, D., Willis, R., Szerszynski, B. and N. Markusson 2019 In: Frontiers in Climate 1:4. doi: 10.3389/fclim.2019.00004.	Rejected - beyond the scope of this chapter	Nils Markusson	Lancaster University	United Kingdom (of Great Britain and Northern Ireland)
18223	23	13	23	15	(Box 6.3) Unclear why the programme in this case study was considered regressive. In what ways was it regressive? Why did it fail to reduce use of traditional fuels? What were the key lessons learnt? Suggest including more details of outcomes and lessons learnt to make the case study informative for readers.	Rejected - no reference is provided; detailed discussion not possible due to space constraints	Government of United Kingdom (of Great Britain and Northern Ireland)	Department for Business, Energy & Industrial Strategy	United Kingdom (of Great Britain and Northern Ireland)
69469	23	15			While the Kero Zero program has been a success, the Government of Indonesia is now willing to reduce LPG imports and the budgetary high cost of LPG subsidies; it intends to do so in shifting cooking from LPG to electricity (see https://situsenergy.com/gugus-tugas-ketahanan-energi-siapkan-kompor-listrik-gantikan-lpg/) .Morocco is also considering electricity as an option for cooking (see e.g. https://www.iea.org/events/towards-clean-and-sustainable-cooking-the-outlook-for-electric-cooking-in-morocco)	Rejected - further discussion about future policy changes not possible due to space constraints	Cédric PHILIBERT	Institut Français des Relations Internationales	France
10923	23	18	23	19	insert ")" into the "(e.g. Sharma et al. 2019," and delete ")" from the "(e.g. Gould 2918)"	Editorial. Noted	Dong-Woon NOH	Korea Energy Economics Institute	Republic of Korea
16347	23	18	23	19	insert ")" into the "(e.g. Sharma et al. 2019," and delete ")" from the "(e.g. Gould 2918)"	Editorial. Noted	Government of Republic of Korea	Korea Meteorological Administration (KMA)	Republic of Korea
17491	23	18	23	18	Typo "(e.g. Sharma et al. 2019)" missing bracket	Editorial. Noted	Alaa Al Khourdajie	IPCC	United Kingdom (of Great Britain and Northern Ireland)
64407	23	28	69	1	The authors do an excellent of acknowledging that the social and environmental impacts of hydropower generation are important and need to be calculated to arrive at the real cost of generated electricity. It would be beneficial to see this level of transparency in the other sections describing mitigation options (e.g., photovoltaics, wind, geothermal, etc.) There is no impact-free energy option, and implementation of the energy transition must come with clear-eye evaluation of the trade-offs and strategies to minimize and mitigate. For example, utility-scale PV facilities in agricultural and desert areas have take land out of production and negatively impact the function of natural communities and threatened and endangered species.	Taken into account. The various mitigation options (wind, PV, geothermal) have been revised.	Curt Bjurlin	Stantec Consulting	United States of America
86309	23	28	69	2	Safety for plant and personnel as well as public should be included in this analysis. Safety should not be compromised for anything including costs.	Rejected. It is not clear what mitigation option this applies to.	RABIZ FODA	Hydro One Networks Inc.	Canada
86311	23	28	69	2	System reliability for electrical power generation, transmission and distribution systems should be included in the analysis.	Taken into account. These sections have been rewritten.	RABIZ FODA	Hydro One Networks Inc.	Canada
86313	23	28	69	2	Hydro power generation as a source of electricity is apparently excluded. Reasons for exclusion to be added with an explanation of potential non-impacts as identified.	Rejected. Hydropower generation is addressed in 6.4.2.3	RABIZ FODA	Hydro One Networks Inc.	Canada

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
86319	23	28	69	2	Consider inclusion of a discussion and implications of water management - specially as it applies to hydro power generation plants.	Taken into account. The implications for water management of hydropower plants is considered in section 6.4.2.3 and in Section 6.5	RABIZ FODA	Hydro One Networks Inc.	Canada
29881	23	29	24	3	A more extensive sub-chapter, adressing state of the art in sustainable energy production development, would be beneficial in this part of the document. Please be encoraged to incorporate more from EU commision here, and in particular the relevant part from the EU taxonomy of sustainable finance regarding energy systems. https://ec.europa.eu/info/sites/info/files/business_economy_euro/banking_and_finance/documents/200309-sustainable-finance-teg-final-report-taxonomy_en.pdf	Rejected. The approach used in this chapter is crosscutting across the entirety of the assessment. So we are following that guidance. Space constraints prevent us from adding a additional concepts or frameworks.	Government of Norway	Norwegian Environment Agency	Norway
85439	23	29	24	3	"Elements of Characterisation" is not a useful headline for people trying to find out (e.g. from the table of content) what to expect. Also: the role of the paragraph in the narrative is completely unclear and it serves to make the entry to the largest paragraph in the chapter a diversion. Please get someone who is not afraid to tell you how it is to edit this chapter. A way to save the information would be to make it into a box so it doesn't distract from the narrative and doesn't serve as the introduction to 6.4.	Noted. We added a sentence to explain that this sections introduces which characteristics of options will be discussed, and what the theoretical rationale is for selecting these	Auke Hoekstra	Eindhoven University of Technology	Netherlands
71561	23	30	23	43	It is indeed important to include other factors than costs but the paragraph can be shortened substantially. One phrase to state that is sufficient.	Noted. We shortened the paragraph	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
20903	24	1	24	3	In Table 6.1, on the first row, about "land use: claims...implemented": no SDG number is given : this item could refer to SDG 15.	Noted. We removed cross references to the SDGs, as impacts of mitigation options on SDGs are discussed in Chapter 17	Government of France	Ministère de la Transition écologique et solidaire	France
20905	24	1	24	3	In Table 6.1, on the 2nd row, about "air pollution (7)": could also refer to SDG 3	Noted. We removed cross references to the SDGs, as impacts of mitigation options on SDGs are discussed in Chapter 17	Government of France	Ministère de la Transition écologique et solidaire	France
20907	24	1	24	3	In Table 6.1, on the 2nd row, about "toxic waste...eutrophication (7)": could also refer to SDG 3	Noted. We removed cross references to the SDGs, as impacts of mitigation options on SDGs are discussed in Chapter 17	Government of France	Ministère de la Transition écologique et solidaire	France
20909	24	1	24	3	In Table 6.1, on the 3rd row: related to SDG 7	Noted. We removed cross references to the SDGs, as impacts of mitigation options on SDGs are discussed in Chapter 17	Government of France	Ministère de la Transition écologique et solidaire	France
20911	24	1	24	3	In Table 6.1, on the 4th row: related to SDG 7	Noted. We removed cross references to the SDGs, as impacts of mitigation options on SDGs are discussed in Chapter 17	Government of France	Ministère de la Transition écologique et solidaire	France
29883	24	1	24	3	Consider to update Table 6.1 with the regarding to energy from key table in the EU taxonomy for Substantial contribution to climate change mitigation page 57-58 in https://ec.europa.eu/info/sites/info/files/business_economy_euro/banking_and_finance/documents/200309-sustainable-finance-teg-final-report-taxonomy_en.pdf	can be a relevant reference indeed, add to line of sight and assessment	Government of Norway	Norwegian Environment Agency	Norway

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
29885	24	1	24	3	Consider to include Cumulative energy demand (CED) as a key indicator for comparing mitigation across energy technologies. Please consider including the study from Modahl et al. (2013) in your assessment. https://www.sciencedirect.com/science/article/pii/S0301421513009294?via%3Dihub	Noted. We are aware that there are many more indicators (several dozens). However, we must also limit it here in this table in order to keep the assessment itself feasible.	Government of Norway	Norwegian Environment Agency	Norway
33053	24	1	24	3	pehaps this question could be added to the Metric: how to re-use existing infrastructures to accelerate the energy transition? For example can the exisitng residential gas biolers be used with hydrogen? Or exisiting gas pipline be used for hydrogen transportation? using hydrogen as a working flow in gas power plants instead of using natural gas [https://www.tno.nl/en/focus-areas/energy-transition/roadmaps/towards-co2-neutral-industry/re-use-of-existing-infrastructure-to-accelerate-the-energy-transition/]	Noted. Investment needs are part of the economic cost assessment - if existing infrastructure can be used, this would be reflected in lower investment needs	Yashar Hajimolana	University of Twente	Netherlands
43871	24	1	24	3	For the environmental-ecological metric: (1) It seems that an indicator for SDG 13 (Climate Action) is not included, despite its interlinked nature with other SDGs especially with SDG 7. One of the indicators o SDG 13 is Indicator 13.2.2 or the total greenhouse gas emissions per year (see A/RES/7/313 adopted by the UN General Assembly). This indicator should be included since fossil fuel-attributed emissions likewise contribute to air pollution. (2) You may think of including impact on wildlife species as an indicator as well since some energy development projects tend to displace them from their natural habitats.	Noted. We removed cross references to the SDGs, as impacts of mitigation options on SDGs are discussed in Chapter 17. Also, please note that climate action is one of the options being assessed against the feasbility indicators included in the table (section 6.4.6). Effects on wildlife are included under biodiversity	Vince Davidson Pacañot	University of the Philippines Diliman	Philippines
43873	24	1	24	3	For the institutional metric: Should policy (statutes, executive orders, etc.) be also included as an indicator for this metric? Mitigation options, most especially renewable energy development, moves forward because of the benefits or privileges (in the form of fiscal and non-fiscal incentives) that are implemented through policies by the government.	Noted. Following SR1.5, we consider policy as an enabling condition that can encourage and promote the adoption of mitigation option by removing barriers for change and strengthening enablers of change that are being assessed in this section	Vince Davidson Pacañot	University of the Philippines Diliman	Philippines
50453	24	1	24	3	Please check the parenthesis tht related to SDG 7	Editorial. Noted	Hoy Yen Chan	ASEAN Centre for Energy	Malaysia
71563	24	1	24	3	Political and societal acceptance are linked, at least in democracies. This should be mentioned somewhere (categories cannot always be distinguished sharply). Why are USD mentioned as the way to measure costs? Could be any other currency?	Noted. Political and societal acceptance may not always be aligned, so we discuss them separetly. We chose USD to harmonise the assessment but it could indeed be any other currency.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
77335	24	1	24	3	The indicators for Environmental-ecological Metrics on Biodiversity (14/15) must be extended to further indicators than "changes in area of conserved primary forest or grassland that affect biodiversity". Other indicators to include are: Impacts on terrestrial and aquatic habitats, species, and nature conservation. The whole table seem to be very limited in choice of indicators, and shoudl be strongly extended	Noted. We are aware that there are many more indicators (several dozens) for biodiversity. However, we must also limit it here in this table in order to keep the assessment itself feasible.	Atle Harby	SINTEF Energy Research	Norway

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
79583	24	1			The reference to SDG here and globally in the report is complex. Having been involved in SDGs proccess since its conception, I have difficulty with such wording. In 2012, a review of SD has been done which complement, reorient previous SD reviews (1992, 2002). Then it was decided that concrete actions before 2030 were urgently needed not to get definitively offtrack. These actions are the targets, which were gropued in domains called SDG. Finally one have on the one hand the SDGs domains which are the domain of SD to be treated transversaly, and 169 specific actions to be done before 2030. Therefore IPCC should use targets in the presentation. Therefore, table 6.1 should have three columns in order to asess barriers and enablers: metric (the domain); description of enablers and barriers; impact on agenda 2030 targets (positive negative) as an indicatoor to contribution to SD which is another dimension. It can be seen as a global complementary constraint for positive integration of energy climate mitigation options. Clearly all will contribute to SDG 13!	Noted. We removed cross references to the SDGs, as impacts of mitigation options on SDGs are discussed in Chapter 17	Marc Daras	CentraleSupelecAlumni	France
84293	24	1	24	3	There is a lack of causality between the indicators measuring the mitigation options.	Noted. Some indicators may indeed be related in some cases, but adding all these would make the table and following assessmnets too complicated and less informative for policy	Vincent MAZAURIC	Schneider Electric	France
1261	24	2	24	3	I think NH4 was meant to be something else?	Rejected. This was meant to be NH4. Representing nitrogen deposition. An important pollutant affecting life on land	Sarah Kurtz	University of California Merced	United States of America
5335	24	2	24	3	In the metric "economic" (middle of the table), the investment cost is not the only parameter. The main one to be considered is the LCOE , mostly in the long term.	Noted. We adopted this indicator from the costs and potential assessment, to align assessments across the report	Michel SIMON	Retraité/ Pdt d'association	France
63637	24	2	24	3	Table 6.1: Air quality (3/7)	Noted. We removed cross references to the SDGs, as impacts of mitigation options on SDGs are discussed in Chapter 17	Government of Canada	Environment and Climate Change Canada	Canada
63639	24	2	24	3	Table 6.1: Toxic waste, ecotoxicity and eutrophication (3/7/12)	Noted. We removed cross references to the SDGs, as impacts of mitigation options on SDGs are discussed in Chapter 17	Government of Canada	Environment and Climate Change Canada	Canada
77363	24	2	24	3	Add changes in habitat on land, freshwater and seawater to environmental impacts	Noted, this is captured in the indicator water quantity and quality	Atle Harby	SINTEF Energy Research	Norway
80141	24	2	24	3	In Table 6.1, it may also be valuable to include free, prior, and informed consent (FPIC under UNDRIP Article 19 and other relevant law) for Indigenous communities as part of equity and justice under 'Socio-Cultural Factors,' paralleling the emphasis on Indigenous advocacy in the preceding chapter	Noted, this issue is discussed in section 6.7.6.2 when discussing equity and procedural justice as a factor influencing acceptability of change.	Robin Happel	Yale Center for Environmental Law & Policy	United States of America
47041	24	3	24	3	For the row on the environmental-ecological metric, the reality of materials to construct renewable energy technologies being extracted through mining minerals (among others) must be recognized, through impacts such as soil contamination by mining waste.	Noted. This is captured by the environmental-ecological dimension	John Leo Algo	Living Laudato Si' Philippines	Philippines
9151	24	4	29	12	Section 6.4.2.1 Solar Energy does not even mention a fundamental characteristic of solar energy: its intermittency. This characteristic should be mentioned and addressed: solar PV does not produce at night, its daily production shows a large annual cycle that is anti-correlated with the present demand in mid to high latitude countries	Accept. We now say "grid integration to address its variability."	Marin Constantin	RATEN ICN	Romania
31449	24	4	29	12	Solar Energy is not a continue production of energy sourde, the generation is variable and depends of wind and solar irradiation, then it varies by day and hour	Accept. We now say "grid integration to address its variability."	Carolina Ahnert	Universidad Politécnica de Madrid	Spain

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
51049	24	4	29	12	Section 6.4.2.1 Solar Energy: it is quite surprising that this section does not even once a (THE) fundamental characteristic of solar energy: its intermittency. Obviously, this characteristic MUST be mentioned and its implications discussed in this section: solar PV does not produce at night, its daily production shows a large annual cycle that is anti-correlated with the present demand in mid to high latitude countries	Accept. We now say "grid integration to address its variability."	Eric PROUST	European Nuclear Society (ENS)	France
71565	24	4	49	13	While the categories and questions for assessing the different mitigation technologies are clearly and broadly introduced they are not followed consistently in the subsections for each technology. Therefore, I suggest to either reduce the emphasis of different assessment categories in the introductory section or follow it more closely for the different technologies. Maybe some subheadings are sufficient.	Noted. Editorial suggestion.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
72149	24	4	29	12	I think this section lacks a critical review of the fact that IAMs, whose results are included in IPCC reports (5th AR and 1.5Special Report), have typically underestimated the mitigation potential of solar photovoltaics. This is one of the most significant criticisms that IPCC 5thAR-Mitigation chapter has received in recent years and it would be great the acknowledge this in the 6th AR. There are several reasons behind this underestimation (outdated cost assumptions in some models, non-realistic over constraints imposed on maximum wind and solar penetration in the grid, etc). It is fine if the section does not go into details, but I think that it is important to emphasize the message that the solar PV has reduced costs and increased global installed capacity much faster than expected, and that that the estimation of its potential contribution to climate change mitigation shall be reviewed and upgraded. The chapter already includes a paper by Creutzig et al, 2017 on this topic, but on top of that the following recent publications reinforced this message and could be used to support all the previous statements: M. Jaxa-Rozen and E. Trutnevyte, Sources of uncertainty in long-term global scenarios of solar photovoltaic technology Nature Climate Change 11 (2021) M. Victoria, N. Haegel, I. M. Peters, R Sinton, A. Jäger-Waldau, C. Cañizo, C. Breyer, M. Stocks, A. Blakers, I. Kaizuka, K. Komoto, A. Smets, Solar photovoltaics is ready to power a sustainable future, Joule (2021)	Noted. Beyond scope of this section.	Marta Victoria	Aarhus University	Denmark
79587	24	4			642. Energy sources and energy conversion. Heat pumps are not mentioned in this chapter while being a key component for heating and cooling and for energy efficiency. A section must be dedicated to it.	Reject. See chapter 5.	Marc Daras	CentraleSupelecAlumni	France
79589	24	4			642. Energy sources and energy conversion. There is no section or subsection on CHP. This is an important feature of composite system, and an important tool for energy efficiency. A section should be devoted to it.	Reject. See chapter 5.	Marc Daras	CentraleSupelecAlumni	France
80343	24	4	24	4	Does not include Synthetic Fuels which offer the possibility of utilising sequestered CO2 and a potential means of decarbonsing sectors were there are not many options for reducing dependence on fossil fuels e.g., aviation	Reject. Text already says: "Solar energy can also be used to produce solar fuels, for example, hydrogen or synthetic gas (syngas)"	Subash Dhar	UNEP DTU Partnership, DTU	Denmark
17339	24	5	24	5	Chapter 6.4.2.1 Solar energy. No word about non-dispatchable nature of the PV. No word about solar PV EROI which is rather low (Weissbach et al, EPJ Web of Conferences 189, 00016 (2018) https://doi.org/10.1051/epjconf/201818900016). No word about solar CSP power-plants, which will need water for cooling. Production of electricity from steam requires cooling water. This process is mentioned as problematic in nuclear power plants due to the water consumption/heating but is not even mentioned with solar CSP. Solar CSP power plant will consume similar amount of water as nuclear power plant of the same size.	Accept. We now say "grid integration to address its variability." We do cover LCA studies including energy consumption in production.	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
20913	24	5	24	5	It is highly surprising that the intermittent characteristic of solar energy is not even mentioned in this section. As some are aware, solar PV does not produce at night, its daily production shows a large annual cycle that is anti-correlated with the demand in mid to high latitude countries	Accept. We now say "grid integration to address its variability."	Government of France	Ministère de la Transition écologique et solidaire	France
51051	24	5	29	12	Section 6.4.2.1 Solar Energy: Solar PV EROI is rather low compared to fossil fuel (as well as to nuclear and hydropower) [1, 2]. This characcteric should be mentioned and its implications discussed [1] D. Weissbach et al, EPJ Web of Conferences 189, 00016 (2018) https://doi.org/10.1051/epjconf/201818900016) [2] Charles A.S.Hall et al., EROI of different fuels and the implications for society, Energy Policy 64 (2014) 141–152, http://dx.doi.org/10.1016/j.enpol.2013.05.049	Reject. This report focuses on climate so our LCA results include those impacts rather than energy related ones.	Eric PROUST	European Nuclear Society (ENS)	France
78745	24	5	29	12	the enormous progress of PV and its impact on the overall energy system also via Power-to-X is not yet fully described. See Haegel et al. (https://science.sciencemag.org/content/364/6443/836) clearly pointing out the huge potential of solar PV to deliver solutions in the terawatt-scale as a fully scalable solution, and a fast scalable industrial output. Such aspects are still missing in this section.	Reject. Text already says: "Solar energy can also be used to produce solar fuels, for example, hydrogen or synthetic gas (syngas)." Length limits preclude longer discussion.	Christian Breyer	LUT University	Finland
79585	24	5			In this chapter on solar energy, there is little reference to solar heating and cooling (p28 ll 23-24). Solar heating plays an important role for domestic use, both in the north and in the south, with different technologies following temperature. It may further plays a role for heating, reducing the demand for electricity. Solar cooling, which is more a niche technology has a potential to face the coming cooling demand, avoiding the use of electricity in the process. They must be convered in this review having a potential for remediation. For data: see for instance REN21 GSR 2020.	Noted but beyond scope due to page limits.	Marc Daras	CentraleSupelecAlumni	France
915	24	6		8	source ?	Noted. Figure 6.8 provides line of sight on costs data.	Alok Dhaundiyal	Szent Istvan University	Hungary
3173	24	6	25	24	The increase in PV capacity factor could be mentionned and explained, just as that of windpower. Cf. Irena (2020) Renewable Power Generation Costs in 2019 p 67	Reject. The change in CF for PV has been very small, whereas wind has clearly improved.	Philippe Quirion	CNRS	France
5337	24	6	24	8	The statement in not correct. It is true that solar costs have declined deeply in the last years, but solar remain as of today the most expensive source, as compared to other renewables, fossil or nuclear. Furthermore, make clear that comparison of costs between intermittent sources and thermal sources is not correct, as you compare carrots and cabbage! Unless you add to intermittent sources the cost of storage or replacement sources. In any case, you cannot state that solar is competitive., in spite of the massive public subsidies it still receives. As a confirmation, check on fig 6.8: Solar has dropped down to ~100$/MWh, when gas or nuclear are around or below 50$/MWh.	Reject. Our data show accurate costs comparisons and we include a section on intermittancy to address it.	Michel SIMON	Retraité/ Pdt d'association	France
9155	24	6	29	12	Please introduce the issue of intermitancy of solar and discuss the predictability of the production and the impact on the energy market.	Accept. We now say "grid integration to address its variability." We do cover LCA studies including energy consumption in production.	Marin Constantin	RATEN ICN	Romania
14683	24	6	24	6	The statement 'the low cost option' should be balanced/nuanced, as it depends on the country/region, as well as financial & technical parameters.	Reject. We already say "in many applications."	Cécile Seguineaud	Indépendant consultant	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
14685	24	6	32	32	In these paragraphs, the assessments that solar and wind are 'low cost options' are based on LCOE data comparisons. However, this metric does not include the value of the electricity produced nor the generated revenues, which may induce a bias in the comparison of the various electricity generation technologies. For instance, the IEA World Energy Outlook reports (2018, 2019, 2020 editions) show that considering a more complete metric such as the Value-Adjusted LCOE (VALCOE) may lead to different results in terms of cost competitiveness of solar and wind technologies.	Reject. We already say "in many applications" and that is accurate.	Cécile Seguineaud	Indépendant consultant	France
51057	24	6	24	7	"Solar PV is increasingly competitive with other forms of electricity generation and is the low-cost option in many applications (high confidence)": Still another misleading statement. Please, indicate/do not omit to say that the "many applications" refferred to are exclusively applications that can accommode being powered only when the sun shines.	Reject. We disagree. The system integration discussion later in this section and later in the chapter cover how variability can be accomodated systemically.	Eric PROUST	European Nuclear Society (ENS)	France
64317	24	6	49	13	There is no mention of water-source heat or waste heat. Both have an important role to play in building heating in conjuction with heat pump technology enabled by district heating in some circumstances.	Noted but beyond scope due to page limits.	Peter North	Imperial College (part-time PhD student) /Calorem Ltd	United Kingdom (of Great Britain and Northern Ireland)
74859	24	6	24	12	An additional limitation for future potential is that several solar PV and wind plants in the pipeline are getting stuck within processes of development for sometime, even after contracts have been signed with the offtaker. This could easily lead to realization of shortfalls in meeting demand especially in the medium term that may necessitate delays in retiring plants (retirements mainly consist of fossi fuel based plants that are in the process of being phased out)	Reject. This is a short term phenomenon and could easily swing the other way once supply chain disruptions are worked out.	Government of Kenya	Kenya Meteorological Service	Kenya
80467	24	6	49	13	Throughout chapter 6.4.2 (and other parts, though here it matters probably most), when speaking about the various energy conversion technologies, power and energy are used inconsistently, for example in 6-48 lines 30-33, the temperature gradient energy is estimated to be 30TW and salinity gradient energy potentials estimated to be over 5,000TWh/year. Jumping between energy and power makes comparing the various technologies difficult. Ideally, always (estimates for) both power and annual energy would be provided (or power and capacity factor) would be provided. For Ocean energy, IRENA has just released a report (December 2020) trying to keep this consistent: https://www.irena.org/publications/2020/Dec/Fostering-a-blue-economy-Offshore-renewable-energy	Reject. This comment does not address the text on the lines indicated.	Moritz Riede	University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
37677	24	7	24	7	It should be made clear that costs can be at generator-end or at consumer-end. In between the generator and the consumer, there is transmission and distribution system. Cost at the consumer-end can be substaintially higher than that at the generator-end. While writing about cost, it should be made clear that cost of solar and wind have declined at the generator-end, while at the comsumer-end, they continue to be high due to system effect. Not conveying this is conveying a false narrative to the polcy makers. (Please refer to Grover, R. B. 2020, "An examination of the narratives about the electricity sector", Current Science, 119(12): 1910-1918.)	Reject. The system integration discussion later in this section and later in the chapter cover how variability can be accomodated systemically.	Ravi B Grover	Homi Bhabha National Institute	India

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
50199	24	7	24	9	The cost decline projections could be better argued by adding few references. The text can be referred to the Figure 6.8. Comparing the text and the figure, the anticipated drop of 16% by 2030 seems an under-estimation. Maybe the author actually meant 16% drop per year till 2030. Few references from IRENA, IEA, BNEF etc can be found compiled on this webpage: https://rameznaam.com/2020/05/14/solars-future-is-insanely-cheap-2020/	the 16% should be amended to reflect the revised costs and potentials exercise.	Rishikesh Joshi	TU Delft	Netherlands
55647	24	7	24	9	Costs are anticipated to decline an additional 16% total by 2030? Why is that decline so much lower than the 62% over the last 4 years? The annual decline over the last 4 years has been approximately 16%.	the 16% should be amended to reflect the revised costs and potentials exercise.	Government of United States of America	U.S. Department of State	United States of America
77161	24	7	24	9	A reference should be added to substantiate the statement.	the 16% should be amended to reflect the revised costs and potentials exercise.	Carles Pelejero	Institut de Ciències del Mar, CSIC	Spain
80443	24	7	24	8	The sentence uses “If current trends continue”, yet if current trends in growth and cost reduction continue, then the cost should fall more than 16%, see e.g. https://www.irena.org/publications/2020/Apr/Global-Renewables-Outlook-2020 (-58% 2018-2030 page 60), https://dx.doi.org/10.1002/pip.3189 (~-40% 2019-2030, abstract), http://www3.weforum.org/docs/WEF_Wind_and_Solar_2030.pdf (“The cost of solar PV energy is projected to halve in the next decade” page 2), https://www.dnv.com/to2030/technology/solar-pv-powering-through-to-2030.html (~-40%) or https://dx.doi.org/10.1002/pip.3189.	the 16% should be amended to reflect the revised costs and potentials exercise.	Moritz Riede	University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
80447	24	7	24	8	Improve the sentence “Cost have...if current trends continue.” by including an absolute reference to “Cost have declined since 2015 by 62% to USD 68/MWh in 2019…” (reasoning: every percentage change needs an absolute value to relate the percentage change to, else the percentage values are not really helpful, and the exact time frame is also needed as the AR6 will be published in 2022 and cost for solar PV are expected to fall further, see e.g. https://dx.doi.org/10.1002/pip.3189 or e.g. https://www.irena.org/publications/2020/Apr/Global-Renewables-Outlook-2020	the 16% should be amended to reflect the revised costs and potentials exercise.	Moritz Riede	University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
28407	24	8	24	8	Should be a rate of 16% per year instead of until 2030 as stated on page 25 line 6. However Vartainen et al. (2019) (Also mentioned on the next page (ine 10) predicts 42-44% reduction from 2019 to 2030 (just 5% per year). https://doi.org/10.1002/pip.3189	the 16% should be amended to reflect the revised costs and potentials exercise.	Naud Loomans	Eindhoven University of Technology	Netherlands
61975	24	8	24	8	Typo: change "are anticipated by an additional 16% by 2030" to "are anticipated todecrease by an additional 16% by 2030"	the 16% should be amended to reflect the revised costs and potentials exercise.	Esa Vakkilainen	LUT University, Lappeenranta	Finland
71567	24	8	24	8	Low confidence should be for the exact percentage but a further cost decline is very probable.	the 16% should be amended to reflect the revised costs and potentials exercise.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
72135	24	8	24	8	"cost declined are anticipated by an additional 16% by 2030" should have high or medium confidence. The learning rate for solar PV has accelerated in the last 5 years and innovations in the pipeline will ensure further cost reduction. The following reference can support this statement. M. Victoria, N. Haegel, I. M. Peters, R Sinton, A. Jäger-Waldau, C. Cañizo, C. Breyer, M. Stocks, A. Blakers, I. Kaizuka, K. Komoto, A. Smets, Solar photovoltaics is ready to power a sustainable future, Joule (2021)	the 16% should be amended to reflect the revised costs and potentials exercise.	Marta Victoria	Aarhus University	Denmark

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
78589	24	8	24	8	why PV shall decline until 2030 ONLY by 16%? This violates major literature. Vartiainen et al. (https://onlinelibrary.wiley.com/doi/full/10.1002/pip.3189) which expresses the insights of European PV experts project a decline of 36% in the base case (2020 to 2030), which is more than twice the number mentioned, while it could be even more in an accelerated PV deployment	the 16% should be amended to reflect the revised costs and potentials exercise.	Christian Breyer	LUT University	Finland
86527	24	8	24	8	" anticipated TO FALL by "	the 16% should be amended to reflect the revised costs and potentials exercise.	raphael Slade	Imperial college	United Kingdom (of Great Britain and Northern Ireland)
51353	24	10			Just over 60% of deployment is now at utility scale {see IEA Solar 2020}	Reject. This is aligned with our statement that "most is now at utility scale."	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
74847	24	10	24	10	The word (high confidence) should be in italics for consistency	Accept.	Government of Kenya	Kenya Meteorological Service	Kenya
76395	24	10	24	15	Solar energy globally is still at the "low hanging fruit" stage where its grid penetration is low and sufficient reliable capacity exists to compensate for its variability. Its future deployment will be limited by high costs of compensatory storage, transmission expansion and ausxilary services. The total amount of solar energy may be potentially large but it cannot be brought to market economically because of overall system costs.	Noted. This view is too pessimistic. We cover grid integration in this section and also later in the chapter.	Robert Parker	Nuclear for Climate Australia	Australia
85341	24	10	24	10	The statement that most is at the utility scale is not exactly right and needs to say that this may be the case more recently but in countries such as Australia where one in five households have solar PV the aggregated impact of this is significant and was driven by a range of factors not necessarily related to subsidies but to increasing costs of fossil fuel electricity and decreasig costs of solar making it more affordable.	Reject. Our statement that "most is now at utility scale" is clearly global and is accurate.	Linda Hancock	Deakin University	Australia
7657	24	16	24	17	I am surprised to see that, in the renewable energy category (4), ther isn't a mention to auctions. The trend worlwide is clearlytowards auctions, see IRENA (2019) Renewable energy auctions. Abu Dhabi.	Noted. Beyond scope due to page limitations for this section.	DEL RIO GONZÁLEZ PABLO	Consejo Superior de Investigaciones Científicas (CSIC)	Spain
917	24	17		18	correct it 'Approximately 120,000 TW of sunlight reaches the Earth’s surface continuously, almost 10,000 times average world energy consumption; factoring in competing land use"	Reject. This is what our text says exactly, no change to make.	Alok Dhaundiyal	Szent Istvan University	Hungary
4175	24	17	24	18	A statement on Milankovitch Cycles - Earth's natural cyclic orbital changes: elliptical, precession, & obliquity osscilations, and their collective effect on long term solar irradiation fluctuations absorbed by the Earth, should be mentioned prior to describing how much sunlight (120,000 TW) reaches Earth's surface.	Reject, beyond scope. Minor changes on 100 year time scales.	Neil M. Mulchan	Adventure Physics, LLC	United States of America
69471	24	17	24	18	The potential has been reassessed at 6200 times the total primary energy consumption in 2008, 4200 tiems that expected in 2035 (IEA, 2011, Solar Energy Perspectives, p.31	Reject, we prefer the more recent 2020 reference.	Cédric PHILIBERT	Institut Français des Relations Internationales	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
75745	24	17	25	1	Reference Dupont et al. 2020 is taken to lightly. The solar potential of 1000 EJ is for integrated solar technologies based on selecting the highest energy return on energy investment providing cells (primarily dominated by Monocrystalline silicon photovoltaic plants combined with Solar tower power plant with molten salt). Based on the same reference it can be also argued that the potential of 184 EJ/year with 67% in Africa and 0% in Europe and NorthAmerica with EROI>=9 is a better estimate of solar potential.	Reject. This is an order of magnitude assessment.	Krešimir Trontl	University of Zagreb, Faculty of Electrical Engineering and Computing	Croatia
77337	24	17	24	18	add ", about half of this energy is used to drive the hydrological circle" after "Approximately 120,000 TW of sunlight reaches the Earth's surface continuously"	Reject, beyond scope of the point we are making.	Atle Harby	SINTEF Energy Research	Norway
84295	24	17	24	18	Replace the Earth's surface by Earth's atmosphere (surface) suitable for the *10000 ratio!	Reject. 120,000TW is at the surface not at the top of the atmosphere.	Vincent MAZAURIC	Schneider Electric	France
323	24		24		NH3, CH4 and fine dust are not the best way to summarise the air pollution elements. I would suggest to stathe in general "... increase or decrease of gaseous and particulate air pollutants..."	Reject. Unclear what this refers to.	Sandro Fuzzi	ISAC CNR	Italy
64821	24		32		There is lack of complex environmental evaluation of Wind and Solar Power Plants (WaSPPs). Those technologies are strongly weather-dependent, which reduces reliability and predictability in electric systems and jeopardize energy security of endpoint electricity consumers. According to current practical experience, every MWe of installed power in WASPPs requires approximatelly 0,8 MWe backup fast-reacting power, which is mostly fossil, natural gas burning power plants. Energy storage technologies are not available in sufficient scale and their environmental impact needs to be thorougly evaulated. Therefore, environmental impact of those backup power plants shall be included into WaSPP technology GHG reduction potential. Another negative consequence of WaSPP implementation is growing demand on high-voltage electric lines capacity, dictated by necessary localization of WaSPPs in suitable areas (e.g. low-populated sunny places, windy seacoasts, shallow seas). Great amounts of electricity from WaSPPs shall be transported to distant consumers using new, high-voltage and high-capacity AC or DC lines. Environmental impact of those lines shall be included into WaSPP technology GHG reduction potential. There is pending environmental and economic issue of unresolved life cycle back-end of WaSPPs. Up to now, there is no mature technology available for safe and acceptable decommissioning, dismantling and recycling of retired photovoltaic panel, batteries and composite parts of wind generators. There is no facility providing such services in industrial scale, necessary for future management of thousands and millions units. In addition, there is also no financial scheme for finacing of this decommissioning, dismantling, recyling and depositioning of used materials. This environmental and economical risk is to be taken into account during evaluation of WaSPP technology GHG reduction potential.	Noted. We discuss grid integration costs in this section and in more detail later in the chapter.	Radek Svoboda	Czech Nuclear Society	Czech Republic

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
84291	24		49		In section 6.4.2, please provide a common framework for comparison: capacity cost per kW or MW, generation cost per kWh or MWh, current trend… Besides, some integration aspects such as the ability to deliver ancillary services to the energy system should be systematically discussed. Especially two features are at concern: (i) the capability to stabilize the system by aggregating inertia in order to ensure (ii) adequacy between supply and demand in 'non-vanishing real time'. Otherwise ther is a risk of black-out under a disturbance in operation or demand fluctuation. A table summarizing these data and uncertainties (or spread) would be valuable	Noted. We cover grid integration aspects in this section and also in latter sections of this chapter.	Vincent MAZAURIC	Schneider Electric	France
86235	24				Table 6.1: Second line, Air pollution. Fine dust should be replaced by fine particles (dust being more often used for natural dust).	Reject. Unclear what this refers to.	Sophie Szopa	LSCE	France
7659	25	1	25	2	FITs are not fiscal policies. They are most often not paid by the public budget, but by consumers in their electricity bills	Reject. Unclear what this refers to. There is no dciussion of policies on page 25, line 1-2	DEL RIO GONZÁLEZ PABLO	Consejo Superior de Investigaciones Científicas (CSIC)	Spain
7661	25	1	25	3	I do not agree with this statement. The evidence shows that FITs are widespread and much more used to promote renewables than regulatory instruments (see, e.g., REN 21 2020 Global Status Report.	Reject. Unclear what this refers to.	DEL RIO GONZÁLEZ PABLO	Consejo Superior de Investigaciones Científicas (CSIC)	Spain
43493	25	1	25	3	Please add " Iran Plateau" phrase after " Arabian Peninsula". The description of the resean is as follows: One of the main important and potent areas for this object is Abarkuh that has long time suny day. It is situated in the western part of Yazd Province. Topographically, the Abarkuh Plain falls within the Central Iranian Plateau and is surrounded by the Zagros Mountains to the south and west. (F.A. Ahmad, Valuation of solar power generating potential in Iran desert areas,Journal of Applied Sciences and Environmental Management,Vol. 22 No. 6 (2018),DOI: 10.4314/jasem.v22i6.21)	Accept. We now say "the middle east."	sadegh zeyaeyan	Head of national center for forecasting and weather hazards management of Islamic Republic of Iran Meteorological Organization (IRIMO)	Iran
50399	25	1	25	3	Please add " Iran Plateau" phrase after " Arabian Peninsula". The description of the resean is as follows: One of the main important and potent areas for this object is Abarkuh that has long time suny day. It is situated in the western part of Yazd Province. Topographically, the Abarkuh Plain falls within the Central Iranian Plateau and is surrounded by the Zagros Mountains to the south and west. (F.A. Ahmad, Valuation of solar power generating potential in Iran desert areas,Journal of Applied Sciences and Environmental Management,Vol. 22 No. 6 (2018),DOI: 10.4314/jasem.v22i6.21)	Accept. We now say "the middle east."	Government of Iran	Islamic Republic of Iran Meteorological Organization (IRIMO)	Iran
919	25	4			comma after world	Reject. Unnecessary.	Alok Dhaundiyal	Szent Istvan University	Hungary
927	25	4			where are those parts ? 'many parts of the world' add sources and mention the name.	Reject. Beyond scope given page limitaitons for this section.	Alok Dhaundiyal	Szent Istvan University	Hungary

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
1527	25	4	25	14	While the comments in this section are correct, except where noted below, the IRENA utility scale PV costs quoted here (USD 68/MWh) differ from corresponding figures quoted in other sections of the report in that they are deduced from ACTUAL 2019 capital costs (resulting value is the weighted average deduced LCOE as stated) rather than being estimates for a new system being installed as in other sections. This gives a distorted view compared to, for example, nuclear, where apparently aspirational (unreferenced) LCOE "in the range of USD 42 and 102/MWh" (mid-range USD USD 72) is quoted, making costs sound quite similar. In reality, the only ACTUAL nuclear LCOE transparently available to me is that for the Hinkley C plant (presently under construction beginning in 2018 and well positioned to "to benefit from the accumulated experience to control main cost drivers") with inflation adjustable costs of GBP92/MWh in 2012GBP (GBP106 in present value or USD147/MWh, inflation adjustable unlike normal LCOE, likely to be above USD170/MWh by project completion, now slipping to 2026), quite different from actual PV prices. To counter such bias, it is important to include somewhere in each section independently published costs for new systems of different types published annually by sources regarded as reasonably reliable such as Lazard or the IEA in their WEO (only for US, Europe, India and China). These give 2020 costs for utility scale PV of USD29-42/MWh and USD35-55/MWh, respectively, and, for nuclear, USD129-198/MWh and USD65-150/MWh (the IEA has historically been biased towards nuclear and away from renewables, as these figures suggest and further demonstrated in comment No.17 below, although both sources are roughly consistent and more representative than the figures appearing in the present draft).	Noted. We have updated values to 2020. Most of this comment is related to nuclear power.	Martin Green	UNSW Sydney	Australia
5339	25	4	25	5	I deeply regret, but this is a lie! See above comment. You are still comparing, as the solar and wind lobbyist does, the cost of a service available when you need it (production by thermal plants) to the cost of a service available from time to time, even when you don't need it. IPCC cannot endorse such mystification.	Reject. Levelied cost is a standard way to compare technology costs. To be sure, there are other factors to consider. For example, we discuss the costs of grid integration in this section and also later in this chapter.	Michel SIMON	Retraité/ Pdt d'association	France
78607	25	4	25	14	it is problematic that the sole basis for cost reductions is IRENA, while it is well known in the PV community that the average cost there are higher as noticed in markets. The reason is the very low-cost projects are not disclosed in their cost and finally not included in the IRENA database, thus leading to too high average cost in the IRENA database. It shall be provided more information in this paragraph on different cost insights from other sources. One of the best additional reference is the PV programme of the IEA with its excellent annual trends reports (https://iea-pvps.org/wp-content/uploads/2020/11/IEA_PVPS_Trends_Report_2020-1.pdf). There one can find figures 6.3 and 6.10 which both describe lower prices - in fig. 6.3 for the global industrial cost curve of all market segments, while in 6.10 the development of best tenders are shown, which clearly indicate the development of the technology. It shall be clearly mentioned on what cost levels PV power plants are built right now in the world, which is consistently for 20 USD/MWh and less in several markets - this is MUCH lower than the indicated numbers based on IRENA, thus the sole mentioning of IRENA numbers delivers a substantially distored view on the cost topic.	Noted. We have updated values to 2020.	Christian Breyer	LUT University	Finland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
78609	25	4	25	14	cost for Europe are shown for utility-scale plants by Vartiainen et al. (https://onlinelibrary.wiley.com/doi/full/10.1002/pip.3189) for Europe, which are partly substantially (-50%!) lower than reported by IRENA, why least cost tenders are further below. A broader variety of cost sources has to be provided for providing a real picture on cost	Reject. We are focused on globally comprehensive data for this assessment and IRENA is the most comprehensive. Going into regional differences is beyond the scope of this section.	Christian Breyer	LUT University	Finland
84297	25	4	25	6	Which costs are compared between fossil and PV? PV costs are dependent of the final quality required by the grid, actually given by dispatchable sources, i.e. additional costs have to be included for variables sources. Besides connection to the distribution or transmission grid entails also over-costs.	Reject. We discussion addiotnal grid integration costs later in the section. Similarly fossil fuels create climate damages and other negative impacts which are not included in their LCOE. Still it is a useful comparison.	Vincent MAZAURIC	Schneider Electric	France
28409	25	6	25	6	Splitting the costs per MWh between utility scale and household systems in high and low yield locatios would give more insight into the cost dynamics	Noted. But beyond scope of this analysis.	Naud Loomans	Eindhoven University of Technology	Netherlands
52167	25	6	25	6	The statement that $68/MWh of PV that near the bottom of the range of fossil fuels is not correct; in many regions fossil generation of electricity, such as from natural gas, is much less expensive.	Reject. We say $68 is near the bottom of the range for fossil fuels given by IRENA. This is accurate.	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
1529	25	8	25	8	"10:90" should correctly be "5:95"	Accept.	Martin Green	UNSW Sydney	Australia
921	25	9			labour	Accept.	Alok Dhaundiyal	Szent Istvan University	Hungary
923	25	11			hyphen missing after utility	Accept	Alok Dhaundiyal	Szent Istvan University	Hungary
925	25	11			avoid comma after installations	Accept.	Alok Dhaundiyal	Szent Istvan University	Hungary
1531	25	13	25	14	"Globally, the range of global PV costs overlapped almost exactly with the range of prices from coal and natural gas". The IRENA report, which I believe is the source of this statement, actually reports "2019 saw 28 GW (40% of utility-scale deployment) of utility-scale solar PV projects commissioned having lower costs than the cheapest fossil fuel-fired option" which seems to better reflect reality than the present statement.	Accept. We now say "Globally, in 2020 the range of global PV costs overlapped with the range of prices from coal and natural gas"	Martin Green	UNSW Sydney	Australia
78591	25	13	25	13	the statement 'with particular low prices in India and China' shall be expaned to 'India, China and Europe', as the cost difference is marginal - see the in the same line used reference Vartiainen et al. which states that quite clearly for the case of Europe	Accept. We now say "China, India, and parts of Europe"	Christian Breyer	LUT University	Finland
80449	25	13	25	16	Make the sentence “Globally, the range...from coal and natural gas.” more precise by changing it to “Globally, the range...from coal and natural gas in 2019, with the cost of PV continuing to drop.” (reasoning: key statements like cost comparisons for technologies what the cost are rapidly changing need a timestamp and a projection to make sense)	Accept. We now say "Globally, in 2020 the range of global PV costs overlapped with the range of prices from coal and natural gas"	Moritz Riede	University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
15095	25	14	25	17	There is a problem with the legend in Figure 6.7. The annual horizontal total radiation cannot be only 1-8. 1-8 should be the daily value rather than the annual value.	Accept. Changed caption to daily.	Guoquan HU	National Climate Center of China Meteorological Adminstration	China
80143	25	14	25	17	I thought this figure was very evocative and well-illustrated	Noted.	Robin Happel	Yale Center for Environmental Law & Policy	United States of America
1263	25	15	25	16	The units used in Fig. 6.7 should be kWh/day/m2. Or, it could be "annual mean daily irradiance" with the current units.	Accept. Changed caption to daily.	Sarah Kurtz	University of California Merced	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
4173	25	15	25	15	Relabel graph with "Effective Cross-sectional Irradiation."	Reject. Metric shown is mean global horizontal irradiation.	Neil M. Mulchan	Adventure Physics, LLC	United States of America
10633	25	16	25	16	irradiation (top of figure 6.7) differs from irradiance (in legend). I believe the figure is right and the word in the legend ought to be replaced by "irradiation"	Accept. Changed to "irradiation."	Philippe Waldteufel	CNRS	France
69483	25	19	25	19	Is there a "Chapter 16"?	Reject. Yes, there is a chapter 16.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
69485	25	19	25	19	Two important drivers of PV cost reductions should be mentioned here: the constant increase in efficiency, and the reduction of financing costs that was eased by two major factors: the dissipation of technology risks and the reduction of market risks provided by policies such as feed-in tariffs, premiums or by utility and company policies of signing long term power purchase agreements.	Accept. Longer explanation is beyond scope here and included in chapter 16; we add efficiency here.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
77163	25	19	25	19	Consider especifying BOX 16.2 within Chapter 6, or being more specific on the pertinent sections of this chapter 16 that deal with the topic.	Noted. We do refer to chapter 16.	Carles Pelejero	Institut de Ciències del Mar, CSIC	Spain
78593	25	19	25	22	the statement that 30% of the total PV cost were module cost is not true in general. This may be true for rooftop segments, but not for industrial roofs in MW-scale and for sure not for utility-scale PV power plants, thus adjustment is necessary. Use the Vartiainen et al. reference with detailed cost insights for Europe which clearly states in the article a value of 43% for the year 2019.	Accept. We now say the 30% refers to rooftop.	Christian Breyer	LUT University	Finland
51355	25	21			which now account for only 30% of installed costs { is this for utility scale installations?}	Accept. We now say the 30% refers to rooftop.	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
14687	25	22	25	24	This study could be added : doi:10.1088/1748-9326/11/11/114010, The role of capital costs in decarbonizing the electricity sector - Lion Hirth and Jan Christoph Steckel	Accept. Citation added.	Cécile Seguineaud	Indépendant consultant	France
15815	25	22	25	24	"Financing costs are an especially important barrier in developing countries and growth there depends on access to low-cost finance." Low cost finance heavily depends on market design and regulation. IEA World Energy Outlook 2020 (comments on Table 5.1) shows that the cost of solar PV, and more specifically its financing cost, can dramatically increase for merchant plants in stark contrast with solar PV with long term contracts (PPA or Power Purchase Agreement). This remark is applicable to all other capital-intensive decarbonised technologies (wind power, hydro, nuclear, fossil-fuel with CCS, electricity grids and electricity storage (batteries, pumped-hydro... associated with power generating technologies). This reason for lower financing cost is similar to the one mentioned by Steckel, Jakob, 2018 (The role of financing cost and de-risking strategies for clean energy investment. Int. Econ.) in this report: it is a de-risking strategy.	Noted. Beyond scope of this section.	Jean-Michel Trochet	EDF group (French Utility)	France
85005	25	22	25	24	cost of capital for CSP decreasing fast but access to climate finance is not available, See recent studies by IRENA	Noted.	Roque Pedace	UBA.Buenos Aires University	Argentina

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
7989	25	27	25	30	The statement that CSP cannot compete with PV-battery systems is not entirely correct. At current technology cost, CSP+thermal storage is cheaper than PV+batteries for all storage durations above 4 hours, i.e. all evening and night power needs. As technological progress is very fast especially for batteries, this may change in teh future, but it is likely that CSP+thermal storage will remain the cheapest option for base load and all storage durations exceeding 8 hours, hence including night-time solar power. See Schöniger et al 2021: https://www.tandfonline.com/doi/full/10.1080/15567249.2020.1843565	Reject. We say "CSP electricity can be more valuable however, because CSP systems can store heat for several hours"	Johan Lilliestam	Institute for Advanced Sustainability Studies & University of Potsdam	Germany
85007	25	27	25	30	areas with DNI above 6000 are suitable for CSP.map is not good enough since it shows horizontal radiation.It can compete with fossils and PV plus storage for many purposes increasing flexibility, H2 production and heat supply. Valuable not evaluable	Noted. Beyond scope of this section.	Roque Pedace	UBA.Buenos Aires University	Argentina
1533	25	28	25	30	"although it will be difficult for CSP to compete with PV and even hybrid PV-battery systems. CSP electricity can be more evaluable however, because CSP systems can store heat for several hours." This last sentence doesn't really make sense since hybrid PV-battery systems can store electricity for several hours (note the typo as well).	Reject. Batteries cannot store much beyond 4 hours in commercially deployed batteries in 2021.	Martin Green	UNSW Sydney	Australia
929	25	29			comma before however 'evaluable?'	Accept	Alok Dhaundiyal	Szent Istvan University	Hungary
43559	25	29	25	29	I guess that by "evaluable", authors meant "valuable". "useful" is probably a better choice of words here	Accept	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy
52169	25	29	25	30	CSP is limited in its location; needs to be mentioned.	Reject. We already say this. "However, unlike PV, only direct sunlight can be concentrated for electricity generation in CSP, constraining its cost-effectiveness to North Africa, Middle East, Southern Africa, Australia, the Western U.S., parts of South America (Peru, Chile), the Western Part of China, and Australia "	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
81059	25	29	25	29	Change evaluable to valuable.	Accept	Aaron Barkhouse	SunPower Corporation	United States of America
64611	25	30	25	30	What does "evaluable" mean in this context; or is it a typo and shold be "valuable"?	Accept	Government of Netherlands	Ministry of Economic Affairs and Climate Policy	Netherlands
78595	25	30	25	30	to be added for the last sentence "... because CSP systems can store heat for several hours, which is also possible for hybrid PV-battery systems and increasingly competitive due to the faster cost reduction of PV and battery systems." - The point is that the PV module LR is 40% and the overall system LR is about 20% leading to the 16% cost reduction per year as stated, and batteries have a 10% cost reduction per year, so that hybrid PV-battery systems become very fast competitive.	Accept. We now say: "CSP electricity can be more valuable however, where CSP systems can store heat longer than PV battery systems."	Christian Breyer	LUT University	Finland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
7987	26	1	26	1	The costs of CSP are not exactly right, or are at least contradicted by our own work, in particular Lilliestam et al 2017 Nature energy (dx.doi.org/10.1038/nenergy.2017.94) and Lilliestam et al 2020 (https://doi.org/10.1080/15567249.2020.1773580). Especially the costs in earlier years are depicted as too high. To some extent, this is likely due to different assumed interest rates, but our data - other than the IRENA data - is based on the stated generation of all CSP stations and the stated costs of each of them individually. Hence, our estimated LCOE decrease from about USD 0.25 per kWh in 2012 (which is when your graph starts) to about USD 0.12 per kWh in 2020, whereas your data goes from approximately USD 0.35 per kWh in 2012 to USD 0.2 per kWh in 2019. See also the data published at www.csp.guru (which is the data from the two cited publications, among others).	Accept. We now say: "Other data sources put recent CSP costs at $120/MWh, in the middle of the fossil range (Lilliestam et al. 2020). "	Johan Lilliestam	Institute for Advanced Sustainability Studies & University of Potsdam	Germany
65793	26	1	26	6	In Fig. 6.8, the curve denoting the lower bound of the the blue area appears to have been saturating in recent years. As this curve points the mark of the lower 10th percentile, is it realistic to assume that the median cost would keep plummeting at the learning rates observed, especially since the median has consistently shifted towards this lower bound? How is this observation taken into consideration in scenario modelling?	Noted. The explanation is that more systems are installed in sunny low cost locations.	Eero Hirvijoki	Aalto University	Finland
80431	26	1	26	5	Please clarify: what is the scientific reason for fitting two linear curves to the LCOE vs time for solar PV? The separation in pre AR5 and post AR5 seems to be arbitrary. Furthermore, a linear fit does not really make sense here, as the LCOE for solar PV would become negative mid 2020s.	Reject. The curve shows the trend in cost reductions before AR5 vs since AR5. The priupose of the AR6 is to highlight developments since AR5, thus the break in trend shown in the figure.	Moritz Riede	University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
86599	26	1	26	6	Figure 6.8 is very troubling. Why have the authors split the trends in the data before AR5 and after? Surely AR5 had no impact on the cost of PV? If it is to show why the AR5 model runs so poorly anticipated the cost declines in solar then this needs to be explained somwhere in the text and surely that is not more important than showing the actual trend in solar PV through time, which has many more years of record and is logistic (see chapter 2, FIgure 2.28 and Farmer, J. D., & Lafond, F. (2016). How predictable is technological progress? Research Policy. https://doi.org/10.1016/j.respol.2015.11.001)	Reject. The curve shows the trend in cost reductions before AR5 vs since AR5. The priupose of the AR6 is to highlight developments since AR5, thus the break in trend shown in the figure.	Matthew Ives	University of Oxford	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
48593	26	2	26	6	This is the first appearance of "LCOE" in this chapter. The authors are clearly aware of the shortcomings of LCOE. Later on p. 31, this text appears: "System integration costs, which are not included in LCOE, are presented in Section 6.4.3." And, of course, system integration are not trivial as renewable penetration increases. LCOE is only one metric of cost, and it can be misleading and misused. It has been widely criticized (example: www.wri.org/blog/2019/08/insider-not-all-electricity-equal-uses-and-misuses-levelized-cost-electricity-lcoe). Comparing intermittent wind and solar LCOE with firm geothermal, hydro, fossil, or nuclear power is comparing apples and oranges. Any reference to LCOE should contain a caveat that LCOE ignores the integration costs of intermittent renewables. For years, Lazard has put this caveat in its LCOE studies: "Other factors would also have a potentially significant effect on the results contained herein, but have not been examined in the scope of this current analysis. These additional factors, among others, could include: capacity value vs. energy value; network upgrades, transmission, congestion or other integration-related costs; significant permitting or other development costs, unless otherwise noted; and costs of complying with various environmental regulations (e.g., carbon emissions offsets or emissions control systems). This analysis also does not address potential social and environmental externalities, including, for example, the social costs and rate consequences for those who cannot afford distributed generation solutions, as well as the long-term residual and societal consequences of various conventional generation technologies that are difficult to measure (e.g., nuclear waste disposal, airborne pollutants, greenhouse gases, etc.)" www.lazard.com/media/451419/lazards-levelized-cost-of-energy-version-140.pdf	Noted. LCOE is one metric and useful because very diverse technologies can be compared. We do talk about system integration costs later. Simialrly the fossil fuel costs here do not include externalities.	Karl Hausker	World Resources Institute	United States of America
7663	26	7	26	9	This is also the aim of generation-based subsidies like FITs.	Reject. This comment does not correspond to the cited page and line numbers.	DEL RIO GONZÁLEZ PABLO	Consejo Superior de Investigaciones Científicas (CSIC)	Spain
69487	26	7	26	9	Which electric systems today have sufficiently "large amounts of PV" to justify that "the cost of integrating large amounts of PV are becoming an increasing share of the total costs of PV-intensive energy systems"? Except for small Islands, presumably CAISO is the most relevant example with 18.7% of annual load in 2019 provided by solar. It would be interesting to try and document this statement. According to Mills et alii, 2021, Solar-to-Grid, USDOE & Berkely national lab, the market value of solar has significantly decreased from 2012 to 2019 as its penetration increased (the energy value has been slowly increased in recent years, but the capacity value has strongly decreased from +40% of the value of a flat block of power to -31% of that value). However, the cost of solar decreased at a similar pace than its market value, thus maintaining solar's overall competitiveness.	Noted. Beyond scope of this section.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
81061	26	7	26	21	While there are undisputed costs associated with a large increase in distributed energy resources (DERs) on the grid, these must be balanced against the savings associated with DERs, including avoided transmission investments and increased local resilience during grid outages.	Noted.	Aaron Barkhouse	SunPower Corporation	United States of America
931	26	9			include	Accept.	Alok Dhaundiyal	Szent Istvan University	Hungary
933	26	11			hyphen missing after utility	Accept	Alok Dhaundiyal	Szent Istvan University	Hungary

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
7665	26	13	26	14	..and welfare increases in many other cases!! (see del Río et al 2017). DEL RÍO, P., RESCH, G., ORTNER, A., LIEBMANN, L., BUSCH, S., PANZER, C. 2017. A techno-economic analysis of EU renewable electricity policy pathways in 2030. Energy Policy 104, 484-493.	Noted. Beyond scope due to page limitations for this section.	DEL RIO GONZÁLEZ PABLO	Consejo Superior de Investigaciones Científicas (CSIC)	Spain
73947	26	13	26	13	It is not clear what "balancing" means here. Maybe "voltage balancing and control"?	Accept. We now say "voltage balancing and control."	Heleno Miguel	Lawrence Berkeley National Laboratory	United States of America
43263	26	15	26	17	Is the relationship between the energy production potential of each country known and how much it actually produces?	Reject. This comment does not correspond to the cited page and line numbers.	Government of Chile	Ministry of Environment	Chile
935	26	19			Avoid free style english 'remove colon'	Accept	Alok Dhaundiyal	Szent Istvan University	Hungary
28411	26	19	26	19	Additional sources https://doi.org/10.1002/pip.2950	Noted. We already cite Bogdanov et al. here to make a similar point.	Naud Loomans	Eindhoven University of Technology	Netherlands
28413	26	19	26	19	With "storage, demand response, sector-coupling", also include the point of transmission reinforcement made in Brown et al 2018	Accept. We add transmission to this list.	Naud Loomans	Eindhoven University of Technology	Netherlands
72131	26	19	26	19	The following reference supports the statement in that sentence regarding the benefits provided by sector-coupling to integrate solar energy M. Victoria, K. Zhu, T. Brown, G. B. Andresen, M. Greiner, Early decarbonisation of the European energy system pays off, Nature communications 11, 6223 (2020) https://www.nature.com/articles/s41467-020-20015-4	Accept. Citation added.	Marta Victoria	Aarhus University	Denmark
78597	26	19	26	19	sector coupling is described in more detail in Bogdanov et al. (2021) for sectors power, heat, transport, industry and desalination: https://www.sciencedirect.com/science/article/pii/S0306261920316639 - the most detailed sector coupling study known, in regards of sectors and various technologies, as industires are modeled in detail for cement, steel, chemicals, aluminum.	Accept, citation added	Christian Breyer	LUT University	Finland
4573	26	21	26	21	Section 6.4.6 should be Section6.4.3； There are some other citation errors in this chapter, please update uniformly.	Noted.	Shining Zhang	GEIDCO	China
5341	26	22	26	22	Instead of : "Because PV power plants have zero costs to run, they depress the prices in wholesale electricity markets", i would write : " Because PV Power plants have low costs to run, they depress the price in whlesale electricity market in period of hifh production, wchich may lead to negative prices."	Reject. There are no additional costs when PV is producing electricity compared to it not producing electricity. That is why its marginal costs are zero. Maintenance, such as cleaning, has to be conducted regardless of how much the unit produces electricity.	Michel SIMON	Retraité/ Pdt d'association	France
14689	26	22	26	26	This study could be added : https://doi.org/10.1016/j.renene.2020.03.082, Learning is not enough: Diminishing marginal revenues and increasing abatement costs of wind and solar Saptarshi Das*, Eric Hittinger, Eric Williams	Reject. We already cite this paper.	Cécile Seguineaud	Indépendant consultant	France
20915	26	22	26	23	Please note that this argument applies for any production facility: more production reduces prices	Reject. Not true. Systems that dispatch high marginal cost resources like diesel generators would see prices rise.	Government of France	Ministère de la Transition écologique et solidaire	France
25021	26	22			PVs do have a running cost, small but not zero. This includes cleaning, maintaining, and operating the facility.	Reject. There are no additional costs when PV is producing electricity compared to it not producing electricity. That is why its marginal costs are zero. Maintenance, such as cleaning, has to be conducted regardless of how much the unit produces electricity.	Bassam AbuHijleh	The British University in Dubai	United Arab Emirates

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
28373	26	22	26	22	PV systems would have cleaning cost to ensure high efficieny and performance and hence it is erroneous to say it is zero cost to run	Reject. There are no additional costs when PV is producing electricity compared to it not producing electricity. That is why its marginal costs are zero. Maintenance, such as cleaning, has to be conducted regardless of how much the unit produces electricity.	Sanjay Kuttan	Singapore Maritime Institute	Singapore
42977	26	22	26	22	PV plants do not have zero costs to run. There are still costs of routine maintance, vegetation control in some regions, security costs, land leases, etc. They could be considered low cost but not zero.	Reject. There are no additional costs when PV is producing electricity compared to it not producing electricity. That is why its marginal costs are zero. Maintenance, such as cleaning, has to be conducted regardless of how much the unit produces electricity.	Kurt Kornelsen	Ontario Power Generation	Canada
52171	26	22	26	24	Whether price suppression is a problem depends on the role of policy and out of market payments not on the specific technology.	Reject. The zero marginal cost attribute of solar (like wind) is what creates price deflation. We do say "electricity market design" in the next section.	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
69489	26	22	26	22	The theoretical analysis by Hirth 2013 is not confirmed by the results of Mills et alii, 2021, Solar-to-Grid, USDOE & Berkely national lab, the market value of solar has significantly decreased from 2012 to 2019 as its penetration increased (the energy value has been slowly increased in recent years, but the capacity value has strongly decreased from +40% of the value of a flat block of power to -31% of that value). However, the cost of solar decreased at a similar pace than its market value, thus maintaining solar's overall competitiveness.	Noted. We do make the point and cite work comparing cost reductions to value deflation.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
79591	26	22			The sentence should be: "Beacuse PV power planst, together with wind power plants, have zero cost to run, and priority of access to run on the grid, they depress…" The zero cost of fuel is already reflected in LCOE calculation, which shows just a competitive value. The access to the grid of both renewable power plant type(in volume the wind before the solar) they change the order of merit for conventional power plant and the volume of production hours, which rise their LCOE. Therefore, in the present stage they are different mechanisms to reflect better the global cost and propose different market approaches(end of Fit, direct trading with minimal price guarantee...) as mentioned in the end of the §.	Noted. We now say: "Because PV power plants have zero costs to run, they can, at high penetrations and in the absence of adequate incentives to shift demand, depress the prices in wholesale electricity markets, making it difficult to recoup investment and potentially reducing incentives for new installations "	Marc Daras	CentraleSupelecAlumni	France
81063	26	22	26	23	Suggest changing to "Because PV power plants have zero costs to run, they can, at high penetrations and in the absence of adequate incentives to shift demand, depress the prices in wholesale electricity markets, making it difficult to recoup investment and potentially reducing incentives for new installations." THe statement as-is seems to imply that renewables always depresss utility prices, which is only true when they grow sufficiently to displace the lowest marginal cost source of power, thereby reducing rates. This is a good thing for consumers, but can be bad for producers if not addressed through rate design, incentives, etc.	Accept. We now say: "Because PV power plants have zero costs to run, they can, at high penetrations and in the absence of adequate incentives to shift demand, depress the prices in wholesale electricity markets, making it difficult to recoup investment and potentially reducing incentives for new installations "	Aaron Barkhouse	SunPower Corporation	United States of America
84299	26	22	26	22	Cheap but not zero: the cleaning of the PV panel is not free, especially in region where sun is abundant (dust). Thermal constraints are also at concern regarding the ageing of installation (and the relative loss of efficiency of PV cells with high temperatures).	Reject. There are no additional costs when PV is producing electricity compared to it not producing electricity. That is why its marginal costs are zero. Maintenance, such as cleaning, has to be conducted regardless of how much the unit produces electricity.	Vincent MAZAURIC	Schneider Electric	France
937	26	27			at the end (what is AR5?) mention it fifth assessment report?	Reject. AR5 should be familiar to readers.	Alok Dhaundiyal	Szent Istvan University	Hungary
9153	26	27	27	6	Please introduce a phrase on the lifetime of PV panels and the solutions for the waste management, including references on the nature and amount of wastes.	Noted. We already discuss recycling in the section.	Marin Constantin	RATEN ICN	Romania

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
20917	26	27	26	27	PV impact on the environment is also through the use of large surfaces	Reject. There are no additional costs when PV is producing electricity compared to it not producing electricity. That is why its marginal costs are zero. Maintenance, such as cleaning, has to be conducted regardless of how much the unit produces electricity.	Government of France	Ministère de la Transition écologique et solidaire	France
31451	26	27	26	27	Solar energy use large land surfaces	Reject. There are no additional costs when PV is producing electricity compared to it not producing electricity. That is why its marginal costs are zero. Maintenance, such as cleaning, has to be conducted regardless of how much the unit produces electricity.	Carolina Ahnert	Universidad Politécnica de Madrid	Spain
51059	26	27	26	27	PVs impact on the environment in also via the use of large land surfaces (for PV farms)	Reject. There are no additional costs when PV is producing electricity compared to it not producing electricity. That is why its marginal costs are zero. Maintenance, such as cleaning, has to be conducted regardless of how much the unit produces electricity.	Eric PROUST	European Nuclear Society (ENS)	France
76397	26	27	26	38	While this section notes that the LCA emissions of solar PV is circa 80 gr CO2/kWh it fails to account for the companion supports ystems such as the LCA's for batteries, extended tansmission lines, ancilliary services and backup energy generators such as gas turbines, Taken together the propsefts for achieveing deep carbon emissions with solar is remote.	Reject. One could say the same for any other energy technology. LCA of an entire system is ultimately the important metric, as Ch 2 covers, here we focus on individual supply technologies.	Robert Parker	Nuclear for Climate Australia	Australia
79769	26	27	26	38	The issues arisen by the carbon emissions of PV production are not mentioned at all, even though they are significant. In addition, efforts like the EU Preparatory Study on EcioDesign Regulation of PV modules, inverters and systems is not mentioned. It is of high importance as it tries to deliver ecodeisgn approaches in the field. Please see the specific reference https://susproc.jrc.ec.europa.eu/product-bureau//product-groups/462/home	Reject. The LCA values here inlcude GHG emissions in production of PV.	Constantinos Psomopoulos	University of West Attica, Department of Electrical and Electronics Engineering	Greece
939	26	28			land-use 'compound words'	Accept	Alok Dhaundiyal	Szent Istvan University	Hungary
77157	26	28	26	31	The phrase is a bit misleading, consider rephrasing it as: "While PV's most beneficial characteristic is its minimal GHG emissions, a comprehensive assessment of its environmental impacts requires a much broader assessment including life-cycle analysis (LCA) of the PV systems that considers impacts such as resource depletion, land use, ecotoxicity, aquatic eutrophication, terrestrial and aquatic acidification, photochemical ozone formation and particulate matter, amongst others (Mahmud et al. 2018)."	Noted.	Carles Pelejero	Institut de Ciències del Mar, CSIC	Spain
9157	26	29	26	29	While PV's most beneficial "... characteristic is its minimal GHG emissions": please be more clear since considering the whole life cycle the PV GHG emissions is larger than that of wind or nuclear	Accept. We now say "low."	Marin Constantin	RATEN ICN	Romania
20919	26	29	26	29	LCA indicates that the GHG emissions of solar is larger than that of wind or nuclear. Thus it is not "minimal"	Accept. We now say "low."	Government of France	Ministère de la Transition écologique et solidaire	France
51061	26	29	26	29	"minimal GHG emissions": the term minimal is not appropriateand should be replaced by "low". Indeed, life cycle analyses indicate that the GHG emissions of solar is larger than that of wind or nuclear.	Accept. We now say "low."	Eric PROUST	European Nuclear Society (ENS)	France
45475	26	35	26	38	Louwen et al provide a nice picture of the developement of life-cycle GHG emissions from PV (Figure 2): Louwen et al. Re-assessment of net energy production etc., Nature Communications, 6 Dec. 2106	Noted.	Kornelis Blok	Delft University of Technology	Netherlands

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
78599	26	35	26	38	the CO2/kWh numbers mentioned are not based on best manufacturer data. A most comprehensive study with access to ral manufacturing data has been published by Wild-Scholten (https://www.sciencedirect.com/science/article/pii/S0927024813004455), and leads to values of 25-80 gCO2/kWh, but at times when module efficiencies had been 15%, now they are at 20%, with respectively better, i.e. lower CO2/kWh values. Such insights shall be built in for a more comprehensive view on this important topic.	Accept. Citation added. Text now reads: "However, recent estimates that reflect higher efficiencies and manufacturing improvements show lower levels, including a range of 18-60 (Wetzel and Borchers 2015) and central estimates of 80 gCO2/kWh (Hou et al. 2016), 50 gCO2/kWh (Nugent and Sovacool 2014), and 20 (Louwen et al. 2016). These recent values are an order of magnitude lower than coal and natural gas and further decarbonization of the enery system will make them lower still. "	Christian Breyer	LUT University	Finland
941	26	36			their central?	Reject. "their central estimates."	Alok Dhaundiyal	Szent Istvan University	Hungary
78469	26	36	26	38	"Even though GHG LCA estimates span a considerable range of 9–250 gCO2/kWh (Kommalapati et al. 2017), their central estimates of 80 gCO2/kWh for current cells (Hou et al. 2016) and others at 50 gCO2/kWh (Nugent and Sovacool 2014) are …" This data is outdated. Please, do not write "for current cells" and cite a paper from 2016 that uses data from the Chinese PV industry in 2013, when it was in an early stage. Suggestion: LCA estimates of mainstream crystalline Si modules, made in China and mounted in inner Mongolia in a 30MW plant, yield about 13 g of CO2eq per kWh of electricity [Ref: LCA Report for photovoltaic modules (TSM-DE15M(II), TSM-DEG15M.20(II), TSM-DEG15MC.20(II), TSM-DE17M(II), TSM-DEG17M.20(II), TSMDEG17MC.20(II)) by Qiang Yang & Bill Kung, Ecovane Environmental Co., Ltd, November 8. 2020; Environmental product declaration, EDPItaly, declaration number 4789556470.101.1, 10. Jan 2020], which is a continuation of the trend over two decades [Ref: A. Louwen, W.G.J.H.M. van Sark, A.P.C.Faaij, R.E.I. Schropp, "Re-assessment of net energy production and greenhouse gas emissions avoidance after 40 years of photovoltaics development", Nature Communications 7, 13728 (2016), DOI: 10.1038/ncomms13728; T. Wetzel and S. Borchers, "Update of energy payback time and greenhouse gas emission data for crystalline silicon photovoltaic modules", Progress in PV 23, 1429–1435 (2015), DOI: 10.1002/pip.2548].	Accept. Text now reads: "However, recent estimates that reflect higher efficiencies and manufacturing improvements show lower levels, including a range of 18-60 (Wetzel and Borchers 2015) and central estimates of 80 gCO2/kWh (Hou et al. 2016), 50 gCO2/kWh (Nugent and Sovacool 2014), and 20 (Louwen et al. 2016). These recent values are an order of magnitude lower than coal and natural gas and further decarbonization of the enery system will make them lower still. "	Pietro Altermatt	Trinasolar, Changzhou, China	Germany
1535	26	37	26	37	GHG LCA: An important point that needs to be made is that the GHG emissions attributed to PV is not a static figure since emissions stem largely from the energy used in manufacture and deployment. This figure reduces as PV technology improves with the same type of learning rate documented as for PV costs (Görig M and Breyer C 2012 Energy learning curves of PV systems 2012 27th European Photovoltaic Solar Energy Conf. and Exhibition, Frankfurt, pp 4682–92). Also, since emissions based on the present energy mix is used in such calculations, additional reductions will occur as the global energy system decarbonises. Without some comment along these lines, a reader would be likely to deduce that even if we switched to a solar powered world, we would be stuck with GHG emissions arising from solar manufacturing.	Accept. We now say: "These recent values are an order of magnitude lower than coal and natural gas and further decarbonization of the enery system will make them lower still. "	Martin Green	UNSW Sydney	Australia
20921	26	38	26	38	About "[…] below natural gas.": but remain far larger than those of other renewable energy and nuclear	Noted. We now say "low"	Government of France	Ministère de la Transition écologique et solidaire	France
51063	26	38	26	38	"are an order of magnitude lower than coal and a factor of five below natural gas": add "but remain far larger than those of other renewable energies and nuclear"	Noted. We now say "low"	Eric PROUST	European Nuclear Society (ENS)	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
78471	26	38	27	2	"Thin films and organics are half those levels, mainly because they use less material 1 (Lizin et al. 2013) and thus avoid melting large amounts of silicon (Hou et al. 2016)." I suggest to omit this sentence, or find an update as well (a publication from 2013 is clearly outdated).	Reject. These are post AR5 studies and sufficient to substantiate the point that thin films are lower.	Pietro Altermatt	Trinasolar, Changzhou, China	Germany
80453	26	38	27	6	There has been quite some progress in organic and perovskite solar cells over the past years (and definitely since the cited reference Lizin et al. 2013). For example, perovskites solar cell efficiencies have now reached 25.5% in the lab and organic solar cell efficiencies are at certified 18.2% (https://doi.org/10.1002/pip.3371). To update the sentence to reflect the latest developments, replacing "Thin film ... shifting to thin films." with the following would be a good option: "Commercial thin film photovoltaic technologies like CIGS and CdTe have a carbon foot print around 30gCO2e/kWh mainly because they use less material than crystalline silicon and thus avoid melting large amounts of silicon (Hou et al. 2016; Product Environmental Footprint Category Rules Database of the European Union v1.2 2020: https://ec.europa.eu/environment/eussd/smgp/pdf/PEFCR_PV_electricity_feb2020_2.pdf). The next generation of solar cells based on organic and perovskite semiconductors have seen rapid progress in recent years and promise even lower environmental impact. Estimates for life cycle GHG emissions of perovskite solar cells vary between 20 and well over 100gCO2e/kWh, but improvements are expected with commercialisation (https://dx.doi.org/10.1016/j.rser.2018.07.048; https://dx.doi.org/10.1016/j.solmat.2017.03.008; https://cloud.accelopment.com/index.php/s/M6gnN69FFT2jQLQ). First commercially available organic solar cells have been independently verified to have cradle-to-grave GHG emissions of about 15 CO2e/m², which translates to about 5-9gCO2e/kWh in central Europe for the investigated products (https://www.certipedia.com/quality_marks/0000069768?locale=de&certificate_number=C01-2019-07-21246543 ; https://www.heliatek.com/en/technology/sustainability/). Improvements that could reduce future lifecycle impacts of all technologies include higher efficiencies, longer lifetimes, sunny locations, less carbon intensive manufacturing inputs, and shifting to lower material consumption."	Accept. We have updated our explantions of organics and perovskites.	Moritz Riede	University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
69491	27	4	27	6	Indeed, besides continued reduction in material use (notably silicon) and increases in efficiency, the LCA of the global PV industry shows further reduction of LCA GHG emissions as PV installations move from their first locations of deployment (notably Europe) to sunnier countries, and as the power systems providing the electricity needed to manufacture the PV modules gets decarbonised. Please mention that under a 2°C scenario LCA GHG emissions of PV would by 2050 range from 3.5-11.5 gCO2eq/kWh, that is not one but two orders of magnitudes below that of fossil-fuelled electricity generation (Pehl et alii, Understanding future emissions from low-carbon power systems by integration of life-cycle assessment and integrated energy modelling, Nature Energy, Vol 2 December 2017: 939-945)	Accept. We now say: "These recent values are an order of magnitude lower than coal and natural gas and further decarbonization of the enery system will make them lower still. "	Cédric PHILIBERT	Institut Français des Relations Internationales	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
18225	27	7	27	22	(Section 6.4.2.1) This section on the land use implications of large PV power plants would benefit from some discussion of the benefits of integrating landscape-level land use planning into (eg) energy plans and policy development. For example, broad (landscape) scale land use planning can help to avoid negative trade offs by ensuring large renewables plants are not sited on primary / unconverted habitat but rather on already degraded land or in areas where ecosystems are already converted from their natural state. Landscape level land use planning is an important policy tool for mitigating negative environmental (and thus climate) trade offs.	Noted. Beyond scope of this section.	Government of United Kingdom (of Great Britain and Northern Ireland)	Department for Business, Energy & Industrial Strategy	United Kingdom (of Great Britain and Northern Ireland)
20923	27	7	27	7	We suggest a rebalancing because a significant impact of solar Pv is mentioned in one sentence, and then 10 more are used to say it is not a problem	Noted. This is the correct interpretation.	Government of France	Ministère de la Transition écologique et solidaire	France
28415	27	7	27	22	Building integrated PV and in general a large share of PV on buildings and other man-made surface is another possibility to reduce land use issues	Noted. But buildings not at the scale of agriculture and water.	Naud Loomans	Eindhoven University of Technology	Netherlands
65795	27	7	27	10	The claim that a 550x550 km^2 area with 0.2 PV efficiency would be able to meet global energy demand seems a bit unrealistic given logistic limitations. Please avoid making back-of-the-envelope estimates.	Noted. We think a simple example is inisghtful.	Eero Hirvijoki	Aalto University	Finland
78601	27	7	27	22	area impact of PV can be also reduced with hybridisation with wind power plants as onsite hybrid PV-wind power plants, as detailed in Ludwig et al. (https://www.aimspress.com/article/10.3934/energy.2020.5.988)	Noted. But this does not reduce the land use impact of PV so we do not include this.	Christian Breyer	LUT University	Finland
79771	27	7	27	22	The issue of land use for PV systems is of paramount importance. The study do not refer to the use of rooftop installations as mean and key approach to increase capacity and reduce the land demand. The authors of the publications 10.4018/978-1-4666-8222-1.ch006, 10.3390/en14040811, https://www.nrel.gov/docs/fy16osti/65298.pdf, 10.1002/pip.2286. In addition two publications show the potential to utilize solar pavements is a solution фор untapping high solar potential and minimize land requirements in the following publications https://doi.org/10.1016/j.solener.2017.04.016, https://doi.org/10.1016/j.egypro.2018.11.261, https://doi.org/10.1016/j.trd.2021.102753, https://doi.org/10.1016/j.solener.2017.04.016 These two issues along with the proposed literature should be included in this point of land use mitigation for solar PV systems. In addition, the solar pavement should be included in the new approach in utilization of Solar PV potential and starts to be considered as advanced new trending PV application	Noted. But buildings not at the scale of agriculture and water.	Constantinos Psomopoulos	University of West Attica, Department of Electrical and Electronics Engineering	Greece
37123	27	8	27	9	Earth's surface is covered 70% by water mostly by ocean, and considering the waste land out of habitable	Noted.	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37125	27	8	27	9	area may not be substantial for that statement to hold true. The statement should be discussed in the	Noted.	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37127	27	8	27	9	context of waste land (quantification is required) available for solar PVs.	Noted.	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
31453	27	9	27	10	Electricity sorage should be included to compensate for the intermittency of solar and wind electricity generation	Noted. We do include it elsewhere in this section.	Carolina Ahnert	Universidad Politécnica de Madrid	Spain

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
51065	27	9	27	10	"at 20% efficicency…could meet global energy demand": Once more, this statement is misleading. At the very least, add something like "provided it is complemented with low-carbon energy storage to compensate for the intermittency of solar production at this scale"	Noted. We are simily providing an example to put land use needs in context.	Eric PROUST	European Nuclear Society (ENS)	France
5343	27	10	27	10	add, at the end of sentence: at peak production periods.	Noted.	Michel SIMON	Retraité/ Pdt d'association	France
37079	27	11	27	13	The following needs to be highlighted. "To reduce substantially GHG emissions, coal plants need to be phased out which is already happening and likely to happen in most of the countries. That would leave large area for replacing coal plants with other clean energy sources. Replacing coal plants by solar alone is a misnomer to match the energy produced by coal.	Noted. Coal is beyond scope of this section.	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37081	27	11	27	13	For example,a typical 3760 MWe Thermal Power Station occupies about 10 km2 area without ash pond(0.65 Acres/MWe),	Noted. Coal is beyond scope of this section.	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37083	27	11	27	13	(1.511Acres/MWe) 23 km2 with ash pond. This site can be utilised to produce 4800 MWe Nuclear power.	Noted. Coal is beyond scope of this section.	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37085	27	11	27	13	with satisfying exclusion zone criteria. While If this land (23 km2) is used for solar,	Noted. Coal is beyond scope of this section.	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37087	27	11	27	13	considering the capacity weighted average of 7.9 Acres/Mwe, hardly 720 MWe is available from this land (intermittent).	Noted. Coal is beyond scope of this section.	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37089	27	11	27	13	Hence, it is prudent to replace the vacated coal plant area by nuclear. Since nuclear plants occupy very small	Noted. Coal is beyond scope of this section.	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37091	27	11	27	13	area because of its high energy density, the balance area withing the exclusion zone can be utilised for solar PV.	Noted. Coal is beyond scope of this section.	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37093	27	11	27	13	So both can operate complementing each other.	Noted. Coal is beyond scope of this section.	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
85009	27	14	27	21	agrivoltaics is also relevant for albedo optimization and production of residues that could be used for bioenergy.CSP can also enjoy same approach and improve degraded (check typo) land and soil as carbon sink.	Reject. Albedo would be lower with solar.	Roque Pedace	UBA.Buenos Aires University	Argentina
63155	27	16			By providing shade for crops, agrivoltaics can provide complementary decarbonisation and agricultural productivity benefits by reducing water requirements for irrigation. (McCord, G., D. Kanter, J. Sklarew, G. Wu, and M. Jacobson. 2020. “Accelerating Sustainable Land Use Practices in the U.S.,” in America's Zero Carbon Action Plan: Roadmap to Achieving Net Zero Emissions by 2050, 262-281. New York: SDSN. https://www.unsdsn.org/Zero-Carbon-Action-Plan)	Noted.	Jennifer Sklarew	George Mason University	United States of America
60165	27	19	27	20	Especially if artificial water bodies e.g. mining lakes or reservoires are used. Additional mitigation advantages are that the evaporation of the water surface can be reduced and the efficiency of PV is better due to cooling.	Accept. We now add: "and reservoirs where evaporation can also be rediced"	Government of Hungary	Ministry of Innovation and Technology - Climate Policy Department	Hungary

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
69493	27	19	27	19	A large potential for hybrid floating PV hydropower electricity generation (4,251 TWh to 10,616 TWh) with various associated benefits has been identified by Lee et alii, 2020, Hybrid floating solar photovoltaics-hydropower systems: Benefits and global assessment of technical potential, Renewable Energy 162: 1415-1427	Accept. We now include this reference.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
78603	27	19	27	20	the potential of floating PV systems is up to one-third of present day global electricity supply, thus really substantial, as pointed out by Farfan and Breyer (https://www.sciencedirect.com/science/article/pii/S1876610218309858)	Accept. We have added the reference.	Christian Breyer	LUT University	Finland
63157	27	22			Climate change has altered some of these species' migration patterns, which suggests the need for land-use solutions that protect migration patterns while enabling siting of PV installations to promote decarbonisation.	Noted. We address this comment already with the line "Landscape fragmentation creates barriers to the movement of species."	Jennifer Sklarew	George Mason University	United States of America
1537	27	23	27	30	Although quantities used per cell have rapidly reduced so that demand has increased much more slowly than PV production volumes, silver is regarded as critical in silion cell manufacturing. "amorphous silicon and cadmium telluride" should be extended to "amorphous silicon, cadmium telluride and copper indium gallium diselenide (CIGS)", since the added one is now more important than the first one.	Accept. We now say: "amorphous silicon, cadmium telluride and copper indium gallium diselenide (CIGS), "	Martin Green	UNSW Sydney	Australia
65797	27	23	27	24	If there only exists medium confidence, then the sentence "[..] PV materials are widely available, have possible substitutes, and can be recycled [..]" should use the phrasing "can possibly be recycled" instread of "can be recycled".	Reject. There is no doubt materials can be recycled. The confidence is about material demand.	Eero Hirvijoki	Aalto University	Finland
77225	27	23	27	26	There is not even a mention here to the rare earths needed for silicon doping, which are not as much abundant, while somewhere else in the text a concern on resources consumption was stated.	Noted. Rare earths are not a substantial matertial input for PV.	Giacomo Grasso	ENEA	Italy
84301	27	23	27	30	The question of scarcity cannot be adressed technology per technology. There is a cumulative effect at the integration level. For instance, the massive implementation of diluted renewables entails a tension on functional and structural materials (e.g.: the copper to refine from now to 2050 is roughly the double of the amount extracted from Antiquity in the illustrative future of figure 6.1...! [O. Vidal, H. Le Boulzec, C. François. Modelling the material and energy costs of the transition to low-carbon energy. Joint EPS-SIF International School on Energy 2017, Jul 2017, Varenna, Italy. 10.1051/epjconf/201818900018.] It is possible to consider low grade ore, but there is a non-linear effect on energy spent for mining or recycling. An other concern is on Aluminium for which energy content is about 95% of its value.	Noted. The literature we cite accounts for this.	Vincent MAZAURIC	Schneider Electric	France
943	27	25			Aluminium	Reject	Alok Dhaundiyal	Szent Istvan University	Hungary
945	27	26			is	Accept	Alok Dhaundiyal	Szent Istvan University	Hungary
947	27	27			Thin-film	Accept	Alok Dhaundiyal	Szent Istvan University	Hungary
1539	27	27	27	28	Thin-film cells usually involve more material since double-glass encapsulation is usually required to protect from moisture.	Accept. We now say "(except for more glass)"	Martin Green	UNSW Sydney	Australia
71569	27	27	27	30	Thin film cells are more expensive than silicon-based ones - this is there main disadvantage. in addition, they partly rely on scarce materials. Efficiency is less problematic. This needs to be adapted and appropriate papers cited.	Reject.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
1541	27	28	27	28	"not yet achieved high enough efficiency and reliability to account": Manufacturers of these products would dispute this statement - I would suggest replacing by "failed to account".	Accept. We now say: "have so far failed to to account "	Martin Green	UNSW Sydney	Australia

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
64313	27	28	27	28	CO2 emission is decreased by 5.8% (updated from 7%). https://www.iea.org/articles/global-energy-review-co2-emissions-in-2020	Reject. This comment does not refer to the line and page number indicated here.	Takashi Hongo	Mitsui & Co. Global Strategic Studies Institute	Japan
1543	27	29	27	30	"Quantum dots and perovskites": There is no commercial interest in quantum dots in solar cells and very limited academic interest. I would suggest replacing by "Other thin-film approaches, such as based on perovskites, organic solar cells, or earth-abundant, non-toxic materials such as kesterites, either on their own, or layered on silicon, have the potential to further reduce semiconductor material use per energy produced.	Accept. We now say: "Other thin-film approaches, such as based on perovskites, organic solar cells, or earth-abundant, non-toxic materials such as kesterites, either on their own, or layered on silicon, have the potential to further reduce semiconductor material use per energy produced."	Martin Green	UNSW Sydney	Australia
81065	27	29	27	30	Suggest adding "but both require significant advancements in reliability to make a meaningful impact on the PV landscape, making it highly likely that silicon PV will be the dominant PV technology for a decade or more according to the International Technical Roadmap for Photovoltaics (ITRPV)." (https://itrpv.vdma.org/web/itrpv/download#)	Noted. We now say: "Other thin-film approaches, such as based on perovskites, organic solar cells, or earth-abundant, non-toxic materials such as kesterites, either on their own, or layered on silicon, have the potential to further reduce semiconductor material use per energy produced."	Aaron Barkhouse	SunPower Corporation	United States of America
1545	27	31	27	43	EU regulations require 85% collection and 80% recycling of the materials used in PV panels, under the Waste Electrical and Electronic Equipment (WEEE) Directive, which was extended to solar products in 2012."silicon" on line 43 should be "silver". Although there is almost exactly 100 times more silicon than silver in a modern module by weight (Report IEA-PVPS T12-19:2020), 99.9% pure silver price is usually more than $500/kg, meaning that contaminated silicon needing refinement would have to be valued at over $5/kg to be worth more, with pristine silicon (9N+) costs decreasing rapidly over recent years but averaging as low as $6.40/kg over Q2 2020. Aluminium from module frames probably have the highest nett value (value minus cost of extracting), since about 4-5 times as much by weight as silicon and simple to strip off.	Accept. We now say: "maximizing recovery of silver, silicon, and aluminum."	Martin Green	UNSW Sydney	Australia
19183	27	31	27	43	reference to recycling of PV equipment is good, but most of the countries lack institutional capacities of waste treatment, recycling and even collections. A need in institutional strengthening of solid and hazardeous waste management should be more emphasised. see John Pichtel, Waste management practices, 2005	Noted.	Andrei Belyi	University of Eastern Finland	Finland
37121	27	31	27	31	Life of solar PV is mentioned 30 years. Generally, they don't last for more than 20 years.	Reject. Warranties are typically for 30 years.	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
74189	27	31	27	35	This section ignores the fact that solar PV derates at 2%+ per year, so a 30 year lifespan is not consistent with current technology. Additionally, recycling solar PV will be very expensive so most of this will likely end up in a hazardous waste landfill. The cost for the disposal or recycling is not included in the cost of deployment so this is a future cost that is unaccounted for and should be addressed.	Reject. 2% is too high rest is speculative.	Jeffrey Merrifield	Pillsbury Law Firm	United States of America
79773	27	31	27	43	EU has already launched the PV Cycle a voluntary scheme that is now operating g with support of many PV operating and manufacturing companies in EU and managed to recycle millions of PV modules until now and increase its annual recycling capacity. Please see http://www.pvcycle.org/homepage/	Noted.	Constantinos Psomopoulos	University of West Attica, Department of Electrical and Electronics Engineering	Greece
84305	27	31	27	31	30 years is a must in ideal laboratory conditions! In-situ, 20 years seems more credible!	Reject. Warranties are typically for 30 years.	Vincent MAZAURIC	Schneider Electric	France
949	27	37			end-use	Accept. We now say "end of life."	Alok Dhaundiyal	Szent Istvan University	Hungary

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
1547	27	38	27	38	As mentined earlier, over 70% of PV waste is glass which is more similar to building waste than electronic waste.	Accept. We now say: "although most of that is glass and relatively easy to recycle"	Martin Green	UNSW Sydney	Australia
43561	27	40	27	40	Insert "." between "itself" and "Ensuing"	Accept	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy
52173	27	40	27	40	Missing period; this occurs throughout the document. See also p. 38, line 25 among others.	Accept.	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
81067	27	40	27	40	Period required between itself and Ensuring.	Accept. We now say "(except for more glass)"	Aaron Barkhouse	SunPower Corporation	United States of America
951	27	41			Aluminium	Reject	Alok Dhaundiyal	Szent Istvan University	Hungary
953	27	43			article before recovery	Reject	Alok Dhaundiyal	Szent Istvan University	Hungary
84303	27	47	27	47	New PV structures decrease cost, reduce ressource but are often less efficient than Si-based semi-conductors.	Noted. In some cases but not all.	Vincent MAZAURIC	Schneider Electric	France
81069	27	48	27	48	This claim about the value of silicon is somewhat misleading - polysilicon prices are at historic lows, so while reclaiming and recycling at end of life is a good thing from an avoided waste perspective, it is unlikely to result in significant cost savings for the PV modules. Also, other materials, especially silver, are much more valuable on a per kg basis.	Reject. Material costs remain an important portion of costs and those prices can change, as evidence by much higher poly-si costs today than when this comment was submitted.	Aaron Barkhouse	SunPower Corporation	United States of America
6033	27				How prevalent is PV recycling? How does this affect the LCOE when full life cycle costs are considered?	Noted. This is mostly a future problem so present recycling pilots are interesting but not relevant to future recycling needs.	Adam Burak	University of Michigan	United States of America
72133	28	1	28	2	PERC technology represented 65% of market share in 2019. See the following reference: International Technology Roadmap for Photovoltaic (ITRPV) 11th Edition, 2019	Accept. We now say "the majority of production."	Marta Victoria	Aarhus University	Denmark
1549	28	2	28	2	In 2020, PERC accounted for over 80% of production. Need to include a date when talking about rapidly evolving trends.	Accept. We now say "the majority of production."	Martin Green	UNSW Sydney	Australia
78473	28	2	28	2	"… now accounting for a third of production…" update to: "… no accounting for the majority of production…"	Accept. We now say "the majority of production."	Pietro Altermatt	Trinasolar, Changzhou, China	Germany
51357	28	4			Consider adding: Silicon cells that are predominantly n-type rather than p-type	Noted. Outside scope.	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
51359	28	4			are taking over an increasing share of the market, as they can be more efficient.	Noted.	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
71571	28	5	28	6	I am sure the view that building integration of PV lowes overall costs is not uncontested.	Reject. Data show BIPV is cheaper.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
79593	28	7			The sentence on CPV should be somplemented by: "… but need a tracking system to capture direct light."	Accept. We add: "use tracking systems ."	Marc Daras	CentraleSupelecAlumni	France
81071	28	8	28	12	However, since these all have lower efficiency and generally shorter lifetimes compared to silicon PV and, as noted above, PV modules represent <30% of system cost (even lower for residential PV), any reduction in module cost may not translate to lower system cost.	Noted.	Aaron Barkhouse	SunPower Corporation	United States of America
957	28	10			cost of production of Quantum dots is not provided. Are they feasible in large-scale energy production?	Noted. No data yet, not commercially produced.	Alok Dhaundiyal	Szent Istvan University	Hungary
1551	28	10	28	19	There is no serious interest in quantum dots for PV - they offer no advantages and require more careful preparation than standard thin-films. As well as perovskites, main interest is in CIGS, organics and kesterites.	Noted. They are a research effort and could be commercialized at some point. We have moved the disucssion down to reflect lower prioritization.	Martin Green	UNSW Sydney	Australia
78467	28	10	29	10	"...at necessary levels, or whether concerns with retiring fossil power (Section 6.3.4) or challenges with integration of renewables (Section 6.6) will slow or limit this growth." This is negative writing, and grid integration is hardly limiting (please, be aware that there are regions like South Australia that has 70% wind and solar and is destined to reach 100% in 2024). I therefore suggest: "...at necessary levels, and fossil power will be phased out at the required pace (Section 6.3.4) and grid integration will be planned sufficiently ahead (Section 6.6) ."	Reject. Comemnt is misplaced, quoted text not in this section.	Pietro Altermatt	Trinasolar, Changzhou, China	Germany
84523	28	12	28	12	Since organic solar cells were mentioned on 6-27, it might make sense to add one sentence here with some of their properties. One option would be: "Organic solar cells are made of carbon-based semiconductors similar to the ones found in the displays made from organic light emitting diodes (OLEDs) and can be processed in thin films on large areas with scalable and fast coating processes on plastic substrates. The main challenges are raising the efficiency and improving their lifetime (10.1039/d0cc05528j 2020; https://dx.doi.org/10.1002/aenm.202002653 2020)"	Accpet	Moritz Riede	University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
84525	28	12	28	14	A sentence describing perovskites and their challenges better would be "Perovskites, inexpensive and easy to produce crystalline structures, have increase in efficiency by a factor of six in the past decade; the biggest challenge is light-induced degradation as well as finding lead-free efficient compounds or establish lead recycling at the end of the life cycle of the device. (Petrus et al. 2017; Chang et al. 2018; https://dx.doi.org/10.1002/admi.201801758, Wang et al. 2019b; Zhu et al. 2020) A common challenge for all emerging solar cell technologies is developing the corresponding production equipment."	Accept	Moritz Riede	University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
955	28	14			light-induced degradation (add more detail about it) (short comings of Perovskites). Avoid clustering of references	Noted. Beyond scope of this section.	Alok Dhaundiyal	Szent Istvan University	Hungary
81073	28	17	28	19	According to the ITRPV (generally accepted to be the definitive document outlining the likely future of the PV industry) c-Si is expected to dominate the market until at least 2030 (https://itrpv.vdma.org/web/itrpv/download#"), due to continuing module cost declines, increasing efficiency, and proven reliability and bankability.	Noted. Speculative.	Aaron Barkhouse	SunPower Corporation	United States of America
78475	28	19	28	19	"...higher efficiencies in future years." I suggest to add: ", but most of them are in the stage of research rather than development and fabrication".	Noted, we make the point above in that we now say: "A common challenge for all emerging solar cell technologies is developing the corresponding production equipment."	Pietro Altermatt	Trinasolar, Changzhou, China	Germany

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
78477	28	19	28	20	I suggest that here, a Box is placed describing PV in Australia. Australia has by far the highest installed PV capacity per capita and the highest rate of employment of PV per capita in the world. A state of Australia, South Australia, has 70% renewables in their electricity grid, and a roadmap for reaching 100% in 2024. A suitable and competent author would be Prof. Andrew Blakers from the Australian National University, andrew.blakers@anu.edu.au.	Noted. Beyond scope of this section.	Pietro Altermatt	Trinasolar, Changzhou, China	Germany
71573	28	20	2	32	It seems very odd to put space-based PV and CSP/ solarthermal heating in the same category of "other solar technologies". Paragraph needs rewriting.	Reject.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
79595	28	20	28	32	This § is covering diverse niche technology notably for heat. It should be placed after the following § on CSP. Some technology such as solar water heating or solar cooling could deserve more consideration due to their importance and remediation potential (see previous comment)	Accept. We now begin the paragraph: "Alternatives to PV include,"	Marc Daras	CentraleSupelecAlumni	France
79597	28	20	28	23	The first sentence refers to the description of CSP and should be the intro of next § on CSP. A dedicated sentence in this section devoted to "other" solar systems, could mention the potential for high temperature potentially industrial application of CSP.	Accept. We now begin the paragraph: "Alternatives to PV include,"	Marc Daras	CentraleSupelecAlumni	France
84307	28	20	28	44	Please provide a summary for Solar generation: capacity cost per MW, generation per MWh, current trend, capabilty to deliver ancilary services... As dispatchable source, CSP could easily provide ancillary services whereas involvment of variable renewable is questionable. (Indeed, some integration aspects such as the ability to deliver ancillary services to the energy system should be systematically discussed. Especially two features are at concern: (i) the capability to stabilize the system by aggregating inertia in order to ensure (ii) adequacy between supply and demand in 'non-vanishing real time'.)	Noted. Beyond scope of this section.	Vincent MAZAURIC	Schneider Electric	France
7993	28	25	28	27	There are no solar chimneys. Whereas the concept could possibly work in practice, we do not know yet. In order to separate technologies that work (CSP, solar heat/cooling, to some degree solar fuels) from technologies that have not been proven to be meaningful would be helpful. Mixing proven and non-proven technologies risks discrediting the proven (but commercially struggling) technologies.	Accept. We now say : "Solar chimneys, still purely a concept, "	Johan Lilliestam	Institute for Advanced Sustainability Studies & University of Potsdam	Germany
62125	28	25	28	28	Solar Chimneys are a marginal and largely theoretical technology. So far no commercial scale project has been build. Thus it seems fair to safe the space and leave out solar chimneys from the report.	Noted. We include to be comprehensive like section abovbe on PV.	richard thonig	IASS Potsdam	Germany
71575	28	27	28	28	All renewables can be used to produce fuels. It is misleading to place this under solarthermal energy. Please delete!	Accept. We now begin the paragraph: "Alternatives to PV include,"	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
69495	28	32	28	32	Besides PV, solar thermal, not CSP, is the solar technology that delivers by far the largest energy contribution globally (in 2018, 400 TWh heat vs 15 TWh elec for CSP).. See e.g. IEA/ISA (2019), Solar Energy: Mapping the Road Ahead, Figure 1	Noted. We already say solar heating is well established.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
71577	28	32	28	32	I think solar heating is much more widely spread than CSP. Please adapt.	Noted. We already say solar heating is well established.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
62119	28	33	28	34	CSP is a good complement for PV as it is inherently dispatchable and can easily reach several thousand MWh of storage. This would be a good opportunity to refer to the Cerro Dominador (2021) and Noor Energy 1 (2022) CSP projects, which includes 1750 MWh (Cerro Dominador) and 8100MWh (Noor Energy 1) of storage respectivly and, making it 15 and 63 times larger than the Horsedale battery in Australia mentioned in the battery storage section. For reference see for example: Schöniger et al 2021 https://doi.org/10.1080/15567249.2020.1843565	Noted. Beyond scope of this section.	richard thonig	IASS Potsdam	Germany
85011	28	33	28	44	CSP is especially relevant for H2 and synthetic fuels. H2 can be integrated in thermochemical and /or electrochemical processes having carbon from biological sources as input.Eg SOEC using both electricity and heat.	Noted. Beyond scope of this section.	Roque Pedace	UBA.Buenos Aires University	Argentina
4111	28	36	28	37	Mentions Australia twice.	Accept	Tatsuki Ueda	National Agriculture and Food Research Organization	Japan
17493	28	36	28	37	Australia mentioned twice	Accept	Alaa Al Khourdajie	IPCC	United Kingdom (of Great Britain and Northern Ireland)
85779	28	36	28	37	Australia is mentioned twice in this list.	Accept	Government of Australia	Department of Industry, Science, Energy and Resources	Australia
62121	28	38	28	38	To my knowledge there are far less parabolic dishes than linear fresnel reflectors used. So far there were no commercial scale dish projects, so I suggest to swap the former for the latter.	Reject. We already say more about troughs than dishes and we mention troughs first.	richard thonig	IASS Potsdam	Germany
7991	28	43	28	44	The learning rates of CSP (on a per-kW basis!) have been strong (7-17% for 6-8 hours storage parabolic troughs, depending on the time interval, dx.doi.org/10.1038/nenergy.2017.94) although clearly lower than for PV - and the lower deployment of CSP compared to PV has let CSP fall behind in terms of cost, although it was the cheaper of the solar power technologies in 2010. (there are learning rates for no-storage CSP in the same publication, with very high learning rates in 2011-2014, but because that time span is very short, the learning rate for 6-8 hours storage stations of 7-17% cited above are probably the more robust number)	Noted. Beyond scope of this section given length constraints	Johan Lilliestam	Institute for Advanced Sustainability Studies & University of Potsdam	Germany
62123	28	44	28	44	It should be mentioned that eventhough both the cost dynamic and industry diversity point into the right direction, that there are currently no policy schemes open for new CSP projects and no new projects have broken ground anywhere in the world in 2019 and 2020. As cost and technology risk remains high, further policy support is needed to realize further cost reductions. See Lilliestam et al (2020) https://www.tandfonline.com/doi/full/10.1080/15567249.2020.1773580	Noted. Beyond scope of this section given length constraints	richard thonig	IASS Potsdam	Germany
69497	28	44	28	44	A recent innovation is to combine CSP and PV in single systems, where the PV can superheat the thermal storage. This combination allows for reducing the cost of dispatchable solar generation. One such example is the Midelt CSP PV plant under construction in Morocco.	Noted. Beyond scope of this section given length constraints	Cédric PHILIBERT	Institut Français des Relations Internationales	France
84369	29	1	29	1	Please specify the unit for storage capacity.	Noted. Horizontal axis shows "hours".	Vincent MAZAURIC	Schneider Electric	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
85969	29	1	29	3	Figure 6.9: Suggest clarification of the significance of the size of the circles in this figure. Can the authors also please check the y-axis label. Should this be "storage time" rather than "storage capacity"?	Noted. Capacity is in hours. We edit caption to explain size. "CSP plants by storage capacity in hours (vertical), year of installation (horizontal), and size of plant in MW (circle size). "	Government of Australia	Department of Industry, Science, Energy and Resources	Australia
9503	29	4	29	12	The text does not distinguish between solar at different scales of deployment (e.g. domestic vs. large scale ground mounted arrays), even though these raise completely different issues of social acceptance. There are research studies on community acceptance of large scale solar projects (e.g. http://dx.doi.org/10.1016/j.rser.2015.04.047, and https://doi.org/10.1016/j.solener.2020.08.065) and the findings of these studies could be summarised here.	Reject. We say earlier that utility-scale accounts for the majority of installations.	Patrick Devine-Wright	University of Exeter	United Kingdom (of Great Britain and Northern Ireland)
9505	29	4	29	4	A more up to date citation about public support for solar and using government survey data is Roddis et al 2019: https://doi.org/10.1016/j.erss.2019.101226	Accept. Citation added.	Patrick Devine-Wright	University of Exeter	United Kingdom (of Great Britain and Northern Ireland)
71579	29	4	29	12	The pargraph mixes solar energy in general and PV.	Noted. As intended. We add "in summary"	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
10635	29	6	29	6	what does "few downsides" mean? Unless you insert "with" following "friendly", or the like.	Accept, we now say "with."	Philippe Waldteufel	CNRS	France
17495	29	6	29	6	"with" few downsides?	Accept, we now say "with."	Alaa Al Khourdajie	IPCC	United Kingdom (of Great Britain and Northern Ireland)
52175	29	6	29	6	Missing word towards the end of the line.	Accept, we now say "with."	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
78605	29	7	29	9	there is a very strong cost rational to go for PV systems for home owners. This has been analyses in huge detail for all countries globally for PV systems also supplying heat demand and battery-electric mobility demand which is upcoming by Keiner et al. (https://www.sciencedirect.com/science/article/pii/S0038092X19304281) - this has been the by far most comprehensive PV prosumers analysis known by the reviewer	Accept. Reference added.	Christian Breyer	LUT University	Finland
1553	29	11	29	11	High upfront costs are now not an issue in many parts of the world (mainly an issue in the US due the high regulatory costs).	Reject. Financing rates are much higher in developing countries.	Martin Green	UNSW Sydney	Australia
79599	29	11			Landlords as such do not oppose Solar energy! What it is mean here, as all actions for energy efficiency on rented housing, is the sharing of cost and benefit between the landlord and the tenant. Could be covered in a new explicit sentence. This contractual discussion should have some place in the report and I did not check for it.	Accept. We now say: "landlord-tenant incentives."	Marc Daras	CentraleSupelecAlumni	France
9159	29	13	32	32	In Section 6.4.2.2 the variability of wind energy is nor mentioned. Please adress frankly.	Taken into account. A sentence has been added, including link to section 6.4.3. Systems and System Integration.	Marin Constantin	RATEN ICN	Romania

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
17341	29	13	29	13	Chapter 6.4.2.2 Wind Energy. No word about non-dispatchable nature of thewind (pg. 31, line 3-8: low LCOE is nice, but the source is non-dispatchable). No word about EROI. No word about material requirements (rare earths for magnets in wind turbines). Tobias Junne, Niklas Wulff, Christian Breyer, Tobias Naegler, Critical materials in global low-carbon energy scenarios: The case for neodymium, dysprosium, lithium, and cobalt, Energy, Volume 211, 2020, 118532, ISSN 0360-5442, https://doi.org/10.1016/j.energy.2020.118532.	First question is taken into account including a link to section 6.4.3 on system integration.	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
20925	29	13	29	13	It is strange that the issue of wind power variability is not mentioned in this section	Taken into account. A sentence has been added, including link to section 6.4.3. Systems and System Integration.	Government of France	Ministère de la Transition écologique et solidaire	France
31455	29	13	32	32	Wind Energy is not a continue production energy source	Taken into account. A sentence has been added, including link to section 6.4.3. Systems and System Integration.	Carolina Ahnert	Universidad Politécnica de Madrid	Spain
51067	29	13	32	32	Section 6.4.2.2 Wind Energy does not even mention a fundamental characteristic of wind power: its variability. This characteristic and its implications should be mentioned in this section and addressed	Taken into account. A sentence has been added, including link to section 6.4.3. Systems and System Integration.	Eric PROUST	European Nuclear Society (ENS)	France
51069	29	13	32	32	Section 6.4.2.2 Wind Energy: Wind power EROI which is rather low compared to fossil fuel (as well as to nuclear and hydropower) [1, 2]. This characcteric should be mentioned and its implications discussed [1] D. Weissbach et al, EPJ Web of Conferences 189, 00016 (2018) https://doi.org/10.1051/epjconf/201818900016) [2] Charles A.S.Hall et al., EROI of different fuels and the implications for society, Energy Policy 64 (2014) 141–152, http://dx.doi.org/10.1016/j.enpol.2013.05.049	Rejected. The text length is limited to consider every possible topic. In addition, the references provided are rather old or not peer-reviewed.	Eric PROUST	European Nuclear Society (ENS)	France
65505	29	13	29	32	The IPCC quotes a cost decline of 80% for solar over the last decade and a 67% cost decline for batteries since 2015. Both of which align with other estimates. However, the chapter states that the costs for solar are projected to drop an additional 16% by 2030, it does not provide any projection for the cost declines in wind by the end of the decade (section 6.4.2.2). Would it be possible to add this? or a discussion on this?	Taken into account. A new sentence on expected cost reductions by 2050 has been added.	Albertine Pegrum-Haram	European Climate Foundation	United Kingdom (of Great Britain and Northern Ireland)
74191	29	13	32	32	No mention is made of the end of live issues associated with wind turbines. Currently, there is no method to reasonably dispose of carbon turbine blades. https://www.bloomberg.com/news/features/2020-02-05/wind-turbine-blades-can-t-be-recycled-so-they-re-piling-up-in-landfills Additionally, in the absence of programs to pre-pay decommissioning costs after the turbines reach end of life, they will end up as a blight on the landscape. https://earther.gizmodo.com/californias-hills-are-haunted-by-the-ghosts-of-wind-ene-1845534109	Taken into account. See response to comment 75747.	Jeffrey Merrifield	Pillsbury Law Firm	United States of America
75747	29	13	32	32	Waste resulting in decommissioning of wind turbines is not mentioned in the section and it can reach up to 2.9 Mt of blades and 43 Mt for other segments in the next period. Pu Liu, Claire Y. Barlow, "Wind turbine blade waste in 2050", Waste Management, Volume 62, 2017, Pages 229-240, ISSN 0956-053X, https://doi.org/10.1016/j.wasman.2017.02.007. or https://www.npr.org/2019/09/10/759376113/unfurling-the-waste-problem-caused-by-wind-energy?t=1615555460052 or https://www.bloomberg.com/news/features/2020-02-05/wind-turbine-blades-can-t-be-recycled-so-they-re-piling-up-in-landfills	Taken into account. A new sentence has been added and references provided.	Krešimir Trontl	University of Zagreb, Faculty of Electrical Engineering and Computing	Croatia

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
85493	29	13	29	20	Science often has the problem that price developments are not well incorporated if technology changes fast and that seems to be the case here. OFFSHORE WIND The texts states offshore reduced in price by 32% since 2015 and that more reductions towards 2030 are expected (medium confidence). However, Junginger 2020 (DOI 10.1016/B978-0-12-818762-3.00007-8) showed that prices had already declined from 170$/MWh in 2015 to 50-90 in 2021 (based on binding bids). So that's a 47-71% reduction. He also reports that experts expected 120 in 2030. So I think that you could check with your sources and can update either the further improvements in 2030 to high confidence (because they are already reached in 2021) or increase the number of 32%. Other datapoints that point to fast cost reductions are the tenders in the Netherlands that went for 72 euro/MWh (Borsele 1+2) and then 55 (Borsele 3+4) in 2016 while new tenders are now subsidy free, although a connection to the grid is provided by and paid for by the grid operator. (https://english.rvo.nl/information/offshore-wind-energy/borssele-wind-farm-sites-iii-iv) Also, it might be good to check with chapter 15 figure 15.7 that shows the assumptions by IRENA. ONSHORE WIND I propose updating the text along the lines of: "Cost have declined by X% and Y% on land and offshore since 2015 and are expected to decline further by 2030 (high confidence). Recent prices for onshore and offshore wind have seen dramatic declines to around 40 $'/MWh for onshore wind and 70 $/MWh for offshore wind (Junginger et al. 2020; Johnson et al. 2020). This is far more than expected by integrated assesment models and also more than expected by IRENA (see e.g. figure 15.7).	Taken into account. A new sentence on expected cost reductions by 2050 has been added.	Auke Hoekstra	Eindhoven University of Technology	Netherlands
5345	29	14	29	15	As of today, Wind production of electricity is cheaper than solar, but more expansive than Hydro, Coal, gas and nuclear. How can you write this first sentence?? Of course, there is no reference given tio support your statement. And if you find one, you will also find 5 more official reference giving the right information.	Rejected. The text does not claim that the statement is true everywhere "*the low-cost option in many applications.*"	Michel SIMON	Retraité/ Pdt d'association	France
14691	29	14	29	15	This statement should be balanced, as it depends on whether an onshore/offshore facility is considered, as well as the country/region or financial & technical parameters.	Rejected. The text length is limited to consider every possibility.	Cécile Seguineaud	Indépendant consultant	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
50207	29	14	29	17	Nice to see the wind energy section begining with the facts about the reduction in prices over the past years and the future projections. I think this could be emphasized by mentioning the current and future projections for the price ranges for onshore and offshore wind farms around the world. It is evident from IRENA reports that we have been able to achieve the 2030 target costs already by 2020. The onshore wind costs range from \$30-\$50/MWh and offshore wind costs range from \$50-\$90/MWh. References: 1. IRENA 2019: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Oct/IRENA_Future_of_wind_2019.pdf 2. Junginger, et al 2020, see Chapter 6 & 7: https://doi.org/10.1016/C2018-0-04547-8 3. Johnston, et al 2020: https://doi.org/10.1016/B978-0-12-818762-3.00007-8 Another noteworthy example which could be mentioned is about the recent Dutch offshore wind costs. Winning bid for the Borssele I & II was 72/MWh and for Borssele III & IV was 54/MWh in 2016. The winning tender of the Hollandse Kust (zuid) wind farm which took place in 2019 was actually subsidy free except for the grid connection which is provided by the government. References: 1. https://www.rvo.nl/onderwerpen/duurzaam-ondernemen/duurzame-energie-opwekken/windenergie-op-zee/windgebied-borssele-i-en-ii 2. https://english.rvo.nl/information/offshore-wind-energy/borssele-wind-farm-sites-iii-iv 3. https://www.government.nl/latest/news/2019/07/10/vattenfall-to-build-second-unsubsidised-dutch-offshore-wind-farm	Taken into account. We updated the 2020 estimates and included further cost reductions by 2050 using the proposed references.	Rishikesh Joshi	TU Delft	Netherlands

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
19069	29	15	29	17	The Wind Energy paragraph gives a decent overview of the current status of deployed onshore and offshore wind. I would like to see further elaboration on of the statement "further (cost) improvements can be expected by 2030 (medium confidence) if current trends continue." I suggest changing this statement into the following: "further (cost) improvements can be expected by 2030 (medium/high confidence), demonstrated by recently completed projects and tenders already reaching the lower end of the IRENA cost estimates for 2030, which are $30–50/MWh for onshore wind and $50–90/MWh for offshore wind. (IRENA 2019) (Junginger, et al 2020) (Johnston, et al 2020). It is worth noting that the IAM used in AR6 are underestimating cost reductions for 2030 and 2050 compared to IRENA as can be seen in Figure 15.7 in chapter 15 of AR6" (IRENA 2019) https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Oct/IRENA_Future_of_wind_2019.pdf (Junginger, et al 2020, see Chapter 6 & 7) https://doi.org/10.1016/C2018-0-04547-8 (Johnston, et al 2020) https://doi.org/10.1016/B978-0-12-818762-3.00007-8 See further elaboration on the cost improvements in onshore and offshore wind in the two comments bellow	Please refer to response to nearly identical comment 50207.	Emiel van Druten	Technical University of Eindhoven	Netherlands

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
19071	29	15	29	17	Elaboration on cost improvements in onshore wind For onshore wind it is possible to make a reference to Figure 15.7: Cost assumptions IRENA and IAM for PV and Wind in 2020/2030/2050 in Chapter 15 of AR6. It is worth mentioning that Chapter 15, on page 32, line 19 to 25 acknowledges that the IAM are underestimating future renewable energy technology prices. That the IAM are underestimating compared to IRENA is one thing, but a January 2021 tender in Spain in which 998 MW of onshore wind was contracted, saw wind bids ranging from €20/MWh to €28.89/MWh at an average price of 25.31 €/MWh ($24/MWh to $35/MWh, avg. $30/MWh) and have to be constructed by April 2024. These prices are already near the IRENA estimates for 2050, see Figure 24 in the IRENA Future of Wind (2019) report. Lazard finds in their LCOE 2020 report onshore wind prices ranging between $26/MWh to $54/MWh, comparable to the the IRENA estimates for 2030 ($30/MWh to $50/MWh). https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Oct/IRENA_Future_of_wind_2019.pdf https://www.spglobal.com/platts/en/market-insights/latest-news/electric-power/012721-spain-places-3034-gw-in-res-auction-at-eur2475mwh https://www.lazard.com/perspective/levelized-cost-of-energy-and-levelized-cost-of-storage-2020/ Junginger, et al - Chapter 5 - Onshore wind energy https://doi.org/10.1016/B978-0-12-818762-3.00006-6 An excerpt from the abstract: "the overall learning rate for LCOE for data between 1990 and 2017 is 11.4%. Combining this learning rate with anticipated growth in global onshore wind deployment yields a projected LCOE of 3.7$ cents/kWh by 2030, a reduction of approximately 25% from 2018 levels, making it highly competitive with expected	Please refer to response to nearly identical comment 50207.	Emiel van Druten	Technical University of Eindhoven	Netherlands

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
19073	29	15	29	17	Elaboration on cost improvements in offshore wind Junginger, et al - Chapter 7 - Offshore wind energy https://doi.org/10.1016/B978-0-12-818762-3.00007-8 In paragraph 7.3.3. Future outlook on page 115: "As a 2015 starting point, an LCOE of 170 US$/MWh was taken, and for 2030, most experts expected a drop of LCOE to about 120 US$/MWh by 2030. This survey was taken at (or shortly after) the peak of LCOE in UK and German projects. But based on the latest bids, LCOE are expected to decline to 50–90€/MWh already by 2021. This elucidates again the difficulty to make sound projections for offshore LCOE." Levelised cost of energy, A challenge for offshore wind https://doi.org/10.1016/j.renene.2020.06.030 In paragraph 5. Discussion on page 883: "However, the difference in CfDs and how exposure to decreases in wholesale electricity prices is allocated in these arrangements explains how 0 €/MWh bids have been seen in Germany and Netherlands but the last round of auctions in the UK were around £40/MWh. The differences in CfDs does not explain the significant discrepancy between auction results and forecast values for LCOE. Values for LCOE by 2026 (as noted in Section 2) for offshore wind in the UK are predicted to be around £80/MWh, approximately twice current strike prices. This means that either the costs of installing and running an offshore wind farm have to decrease significantly by the time these sites come online or the agreed strike price will have to rise so that the sites are economically viable." To provide an example of the rapid cost reduction in recent years: the Dutch offshore wind farm Borssele I & II tendered in July 2016 for €72.7/MWh and in September 2016 Borssele III & IV tendered for €54.5/MWh and both wind farms completed construction in 2020. Tenders from 2017 onwards were subsidy-free, except for the	Please refer to response to nearly identical comment 50207.	Emiel van Druten	Technical University of Eindhoven	Netherlands
28467	29	15	29	17	The Wind Energy paragraph gives a decent overview of the current status of deployed onshore and offshore wind. I would like to see further elaboration on of the statement "further (cost) improvements can be expected by 2030 (medium confidence) if current trends continue." IRENA estimates $30–50/MWh for onshore wind and $50–90/MWh for offshore wind. (IRENA 2019) (Junginger, et al 2020) (Johnston, et al 2020). These values are already currently obtained, the authoritve Lazard report (2020) states $26/MWh to $54/MWh for onshore and a midpoint of 86$/MWh for offshore. These cost projection are thus already attained. See NREL Annual Technology Database on wind for a greater insight in expected costs for on and ofshore wind towards 2030. (IRENA 2019) https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Oct/IRENA_Future_of_wind_2019.pdf (Junginger, et al 2020, see Chapter 6 & 7) https://doi.org/10.1016/C2018-0-04547-8 (Johnston, et al 2020) https://doi.org/10.1016/B978-0-12-818762-3.00007-8 (Lazard, 2020) https://www.lazard.com/media/451419/lazards-levelized-cost-of-energy-version-140.pdf (NREL, 2020) https://atb.nrel.gov/electricity/2020/data.php	Please refer to response to nearly identical comment 50207.	Naud Loomans	Eindhoven University of Technology	Netherlands

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
69499	29	15	29	17	One solid indication of future cost trends is given by the auctions for ppa, which gives a good indication of the technology costs in the next few years. In case of offshore wind power they suggest signifanctly steeper reductions, with costs that were around 160$ five years ago have been falling down to 44€ in one case at least, 60-70€ in several others.	Rejected. The IPCC assessment is based on published literature.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
75635	29	15	29	17	It would be appreciated if this piece would elaborate on the following statement: "further (cost) improvements can be expected by 2030 (medium confidence) if current trends continue". For example, a discussion could include references to updated research as follows: "further (cost) improvements can be expected by 2030 (medium/high confidence), shown by recently finished projects and tenders that lean towards the lower end of IRENA 2030 cost prognoses ($30–50/MWh for onshore wind and $50–90/MWh for offshore wind. (IRENA 2019) (Junginger, et al 2020) (Johnston, et al 2020)). Indeed , the IAM used in AR6 are providing an underestimation of the potential 2030 and 2050 cost reductions, as emphasized in Figure 15.7 of the AR6 Chapter 15." I. (IRENA 2019) https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Oct/IRENA_Future_of_wind_2019.pdf) II. (Junginger, et al 2020, see Chapter 6 & 7) https://doi.org/10.1016/C2018-0-04547-8 III. (Johnston, et al 2020) https://doi.org/10.1016/B978-0-12-818762-3.00007-8	Please refer to response to nearly identical comment 50207.	Amira El-Feiaz	Technische Universiteit Eindhoven	Netherlands

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
75637	29	15	29	17	To elaborate on the discussion of cost improvements in onshore wind Referring to Figure 15.7 in Chapter 15, page 32, lines 19-25 recognize that the IAM provide an underestimation for the price of (short and long-term) renewable energy technology. This is not only true in comparison with IRENA research; but can also be concluded in light of recent projects. For example, during a tender in Spain this January 2021 (contracting 998MW of onshore wind) wind bids ranged from €20/MWh to €28.89/MWh at an average price of 25.31 €/MWh ($24/MWh to $35/MWh, average $30/MWh), to be constructed by April 2024 latest. Such prices are nearing the IRENA Future of Wind (2019) estimates in Figure 24. Furthermore, in the LCOE 2020 report Lazard provides onshore wind prices to be ranging between $26/MWh to $54/MWh – which is quite comparable to the IRENA estimates for 2030 ($30/MWh to $50/MWh). I. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Oct/IRENA_Future_of_wind_2019.pdf II. https://www.spglobal.com/platts/en/market-insights/latest-news/electric-power/012721-spain-places-3034-gw-in-res-auction-at-eur2475mwh III. https://www.lazard.com/perspective/levelized-cost-of-energy-and-levelized-cost-of-storage-2020/ Moreover, it would be great if the discussion would include the following research findings on learning rate, from Junginger, et al - Chapter 5 - Onshore wind energy (https://doi.org/10.1016/B978-0-12-818762-3.00006-6) An excerpt from the abstract: "The overall learning rate for LCOE for data between 1990 and 2017 is 11.4%. Combining this learning rate with anticipated growth in global onshore wind deployment yields a projected LCOE of 3.7$ cents/kWh by 2030, a reduction of approximately 25% from 2018 levels, making it highly competitive with expected prices of new coal and natural gas generation. A recent expert elicitation study of future costs of wind power yielded a range of implicit future learning rates between	Please refer to response to nearly identical comment 50207.	Amira El-Feiaz	Technische Universiteit Eindhoven	Netherlands

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
75639	29	15	29	17	To elaborate on the discussion of cost improvements in offshore wind The material provided would benefit from including the following up-to-date sources: A.Junginger, et al - Chapter 7 - Offshore wind energy https://doi.org/10.1016/B978-0-12-818762-3.00007-8 Notably, in part 7.3.3. on page 115: "As a 2015 starting point, an LCOE of 170 US$/MWh was taken, and for 2030, most experts expected a drop of LCOE to about 120 US$/MWh by 2030. This survey was taken at (or shortly after) the peak of LCOE in UK and German projects. But based on the latest bids, LCOE are expected to decline to 50–90€/MWh already by 2021. This elucidates again the difficulty to make sound projections for offshore LCOE." B.Johnston, B., Foley, A., Doran, J., & Littler, T. (2020). Levelised cost of energy, A challenge for offshore wind. Renewable Energy, 160, 876-885. (https://doi.org/10.1016/j.renene.2020.06.030) Notably, in paragraph 5, on page 883: "However, the difference in CfDs and how exposure to decreases in wholesale electricity prices is allocated in these arrangements explains how 0 €/MWh bids have been seen in Germany and Netherlands but the last round of auctions in the UK were around £40/MWh. The differences in CfDs does not explain the significant discrepancy between auction results and forecast values for LCOE. Values for LCOE by 2026 (as noted in Section 2) for offshore wind in the UK are predicted to be around £80/MWh, approximately twice current strike prices. This means that either the costs of installing and running an offshore wind farm have to decrease significantly by the time these sites come online or the agreed strike price will have to rise so that the sites are economically viable." To illustrate the potential of the recent rapid cost reduction: the offshore wind farm Borssele I & II in the Netherlands tendered for €72.7/MWh in July 2016, in September 2016 Borssele III and IV tendered for €54.5/MWh. Both wind farms were finished with construction in 2020; tenders from 2017 onwards were subsidy-free, excluding the	Please refer to response to nearly identical comment 50207.	Amira El-Feiaz	Technische Universiteit Eindhoven	Netherlands
84997	29	15	29	17	This sentence could be improved by adding more evidence to it, or cost indicatios of the mentioned improvements. Valuable sources that can be considered for this are: (IRENA 2019) https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Oct/IRENA_Future_of_wind_2019.pdf); (Junginger, et al 2020, see Chapter 6 & 7) https://doi.org/10.1016/C2018-0-04547-8 ; (Johnston, et al 2020) https://doi.org/10.1016/B978-0-12-818762-3.00007-8 By including information (numbers) on the potential of cost reductions it would seem that in fact the AR6 provides an underestimation of the cost reduction potentials towards 2030 and 2050.	Please refer to response to nearly identical comment 50207.	Sofia Rosero Abad	University	Netherlands
10925	29	16	29	16	please insert the numeric cost reduction value of offshore and onshore wind in "further improvement can be expected by 2030" from IRENA(2020), Global Reenewable Outlook, p 35(-55% for offshore, -25% for onshore wind for 2018-2030)	Taken into account. We updated the 2020 estimates and included further cost reductions by 2030 and 2050.	Dong-Woon NOH	Korea Energy Economics Institute	Republic of Korea
16349	29	16	29	16	please insert the numeric cost reduction value of offshore and onshore wind in "further improvement can be expected by 2030" from IRENA(2020), Global Reenewable Outlook, p 35(-55% for offshore, -25% for onshore wind for 2018-2030)	Please refer to response to identical comment 10925.	Government of Republic of Korea	Korea Meteorological Administration (KMA)	Republic of Korea
20927	29	19	29	19	It is strange that land availability is mentionned as an issue for Wind energy, but not so for solar PV	Rejected. The issue is disussed in the solar section as land is displaced for solar farm construction.	Government of France	Ministère de la Transition écologique et solidaire	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
51361	29	19			land availability in wind power-rich areas for onshore deployment, lack of supporting infrastructure	Taken into account.	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
85343	29	19	28	19	There should also be comment on these innovations in materials that there may belimitations in supply, ethical mining and supply chain issues with conflict minerals and rare earths see for eg. Hancock, L, Ralph, N, Armand, M, Macfarlane, D, Forsyth, M 2018. 'In the Lab: New Ethical and Supply Chain Protocols for Battery and Solar Alternative Energy Laboratory Research Policy and Practice, Journal of Cleaner Production, https://doi.org/10.1016/j.jclepro.2018.03.097	Taken into account. A new box on rare earth elements and critical metals has been added.	Linda Hancock	Deakin University	Australia
959	29	21			the wind	Taken into account.	Alok Dhaundiyal	Szent Istvan University	Hungary
10927	29	21	29	23	please differentiate between Energy from wind is abundant in line 21 and the energy from wind near the Earth is abundant, and insert the numeric value for the potential of wind energy	Taken into account. The sentences have been rewritten.	Dong-Woon NOH	Korea Energy Economics Institute	Republic of Korea
16351	29	21	29	23	please differentiate between Energy from wind is abundant in line 21 and the energy from wind near the Earth is abundant, and insert the numeric value for the potential of wind energy	Taken into account. The sentences have been rewritten.	Government of Republic of Korea	Korea Meteorological Administration (KMA)	Republic of Korea
43563	29	21	29	23	The second sentence partially repeats the first one	Taken into account. The sentences have been rewritten.	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy
55649	29	21	30	3	What is the scale of the technical or economic potential of wind power? This value is included in other generation source sections, such as the preceding section on solar power, but it is not included for wind. The inclusion of such a value would be helpful for comparison purposes between generation sources.	Taken into account. A new sentence has been added.	Government of United States of America	U.S. Department of State	United States of America
961	29	27			hyphen 'land-use'	Corrected	Alok Dhaundiyal	Szent Istvan University	Hungary
45477	29	27	29	28	How is "excellent" defined here? 3% seems a relatively low number. The maps in Deng et al. suggest substantially higher %: Deng et al. Quanatifying a realistic worldwide etc. Global Env. Change 31 (2015) 239-252.	Corrected. Excellent wind resources are defined as areas where power densities are above 500 W/m2.	Kornelis Blok	Delft University of Technology	Netherlands
963	29	29			is	Corrected	Alok Dhaundiyal	Szent Istvan University	Hungary
77339	29	29	29	29	substitute "more reliable" with "less variable". Reliable is not very easy to understand	Corrected	Atle Harby	SINTEF Energy Research	Norway
65799	29	30	30	1	"Studies have suggested that 'bottom-up' estimates of wind physical potentials could be overestimated [..] but even in the most conservative estimates the technical wind potential surpasses the amount required for climate mitigation." What exactly is this conservative estimate measured in energy and how does it compare with global energy demand? Numbers are always more meaningful than adjectives so, please indicate this information in the draft.	Rejected due to space limitations.	Eero Hirvijoki	Aalto University	Finland
6035	29				May be good to compare continuous wind energy across the earth to world energy consumption, similar to continuous sunlight on earth's surface (6-24) or gross theoretical hydropower (6-32).	Taken into account. A new sentence has been added.	Adam Burak	University of Michigan	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
69501	30	1	30	1	An important reference here is the IEA 2019 Offshore Wind Power Outlook, that showed a potential for Europe in its Exclusve Economic Zones of about 10 times its current electricity demand.	Taken into account. A new sentence has been added in terms of global energy consumption.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
43265	30	4	30	7	Is the relationship between the energy production potential of each country known and how much it actually produces?	Taken into account. A new sentence has been added in terms of global energy consumption.	Government of Chile	Ministry of Environment	Chile
65801	30	4	30	7	In Figure 6.10, the numbers and the caption are highly misleading. Even in a typical, modern offshore wind farm, such as the forthcoming Dogger Bank A and B in UK, the power-capacity density is 2 W/m^2 (1.2GW capacity and 500-600 km^2). Accounting for a generous capacity factor of 0.5, the average power density is in the order of 1 W/m^2. Fix the caption of the Figure 6.10, and explain what the numbers mean.	Rejected. Estimates are given of the geophysical potential. Wind turbines are placed many rotor diameters apart.	Eero Hirvijoki	Aalto University	Finland
20929	30	5	30	5	The "power density" is not clearly defined in the document. It display indicates that it is somewhat related to the energy that can be extracted with wind turbine (if not, what is the use of this parameter). And if so, the number are clearly wrong. The typical energy that is extracted by a wind farm is typically 1000 times lower than the values that are shown here. So either one explains that the figure is unrelated to the wind energy potential, or the figure must be corrected	Rejected. Estimates are given of the geophysical potential. Wind turbines are placed many rotor diameters apart and that needs to be included in the estimate.	Government of France	Ministère de la Transition écologique et solidaire	France
20931	30	5	30	5	We suggest to change "and 100 km offshore" to : within 100 km of the coastlines	Taken into account.	Government of France	Ministère de la Transition écologique et solidaire	France
51071	30	5	30	7	The definition of "mean wind power density" should be given. For enabling the reader to understand its significance, indication should be provided on the relationship between this "wind power density" and the corresponding "electrical power density" that can be recovered using wind turbines	Taken into account. The term is now explained.	Eric PROUST	European Nuclear Society (ENS)	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
50201	30	8	30	18	The fact about continuous increase in the capacity and size of wind turbines is nicely presented. But I think it could be emphasized further using more recent examples. The largest turbine in the world which is operational and is producing power is GE's Haliade-X (12MW) in Maasvlakte, Netherlands. Please see: https://www.ge.com/news/press-releases/power-generated-ge-haliade-x-12-mw-prototype-rotterdam-be-bought-eneco-utility. Probably it is also worth mentioning the latest announcements by the leading wind turbine manufacturers about their flagship turbines. Please see: GE Haliade-X (12,13, & 14MW): https://www.ge.com/renewableenergy/wind-energy/offshore-wind/haliade-x-offshore-turbine Dogger bank wind farms will be using GE's Haliade-X: https://www.ge.com/news/press-releases/ge-renewable-energy-haliade-x-turbines-be-used-dogger-bank-wind-farms#:~:text=Press%20Release-,GE%20Renewable%20Energy's%20Haliade-X%20turbines%20to%20be,by%20Dogger%20Bank%20Wind%20Farms&text=Dogger%20Bank%20will%20now%20be,become%20carbon%20neutral%20by%202050.%E2%80%9D Siemens Gamesa (14MW): https://www.siemensgamesa.com/en-int/products-and-services/offshore/wind-turbine-sg-14-222-dd Vestas (15MW): https://www.vestas.com/en/media/company-news?n=3886820#! Following is a suggestion for text incorporating above examples that could replace the	Accepted and used in text. Further examples are rejected due to space limitations.	Rishikesh Joshi	TU Delft	Netherlands
77341	30	9	30	9	Replace the word "farm" with "power plants". The power plants producing power from wind, are not "farms" which has something to do with agriculture. Please use correct wording and not populistic wording. This must be changes about 20 places in the document	Rejected. Wind farm is well known term.	Atle Harby	SINTEF Energy Research	Norway
52177	30	15	30	15	Should also report recent sizes, which are much larger than the average size.	Rejected. This is already written.	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
45479	30	16	30	18	I know it is difficult to stay up-to-date in this field. But there is a 12 MW GE turbine operational in Rotterdam, The Netherland. And Vestas announced 15 MW (but maybe not yet operational).	Accepted and used in text.	Kornelis Blok	Delft University of Technology	Netherlands
69503	30	16	30	18	The largest turbine in the world seems to be now the Haliade installled in Rotterdam, initially of 12 MW, now working at 13 MW. Its rotor diameter exceeds 200 m.	Accepted and used in text.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
965	30	17			check article 'a'	Accepted.	Alok Dhaundiyal	Szent Istvan University	Hungary

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
19075	30	17	30	17	"The largest turbine in the world became operational offshore in the Belgian coast in 2020, an 9.5 MW turbine with a rotor diameter of 164 m." This is not correct, I suggest: "The largest turbine in the world became operational in the Port of Rotterdam in the Netherlands in 2019, GE's Haliade-X 12 MW turbine with a rotor diameter of 220 m and there are also 13 MW and 14 MW variants available. These turbines will be commercially installed in offshore wind farms starting in 2021. February 2021 Vestas has announced a 15 MW offshore wind turbine with a rotor diameter of 236 m." https://www.portofrotterdam.com/en/news-and-press-releases/giant-wind-turbine-on-maasvlakte-2 https://www.ge.com/renewableenergy/wind-energy/offshore-wind/haliade-x-offshore-turbine https://www.vestas.com/en/products/offshore%20platforms/v236_15_mw#!	Please refer to response to identical comment 50201.	Emiel van Druten	Technical University of Eindhoven	Netherlands
28417	30	17	30	17	The largest turbine in the world is currently GE's Haliade X (12MW) and 14-15MW turbines have already been announced https://www.ge.com/news/press-releases/power-generated-ge-haliade-x-12-mw-prototype-rotterdam-be-bought-eneco-utility	Accepted and used in text.	Naud Loomans	Eindhoven University of Technology	Netherlands
43565	30	17	30	17	Replace "in" with "on"	Rejected	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy
10067	30	19		24	Are there any protype or pilot installation of floating wind turbines?	Operational floating wind farms alredy exit in Norway and Scotland.	Government of Indonesia	Ministry of Environment and Forestry	Indonesia
60137	30	19	30	19	the word taping to be repalced by 'tapping'	Accepted. Thank you.	Umasankari Kannan	Bhabha Atomic Research Centre	India
2333	30	20	30	20	please change "southeast Asia" to "Asia"	Accepted and used in text.	Nicholas Wagner	International Renewable Energy Agency (IRENA)	Germany
17343	30	21	30	21	"Floating wind farms offer economic …" Reference needed. I doubt in economy of nonexistent technology.	Rejected. Floating wind farms are already operational in the Scotish coast.	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
20933	30	21	30	24	The environmental impacts of floating wind farms are different from those of fixed-bottom wind farms, but they are not always less significant, especially during the whole life of the project (introduction of native species, friction of the anchor lines, etc.). https://www.boem.gov/sites/default/files/documents/environment/Wind-Turbine-Foundations-White%20Paper-Final-White-Paper.pdf Comparisonof Environmental Effectsfrom Different Offshore Wind Turbine Foundations. Sarah Horwath, Jason Hassrick, Ralph Grismala, Elizabeth Diller. BOEM. August 2020	Accepted.	Government of France	Ministère de la Transition écologique et solidaire	France
20935	30	21	30	24	Showing an outline would be of great interest for these values to be better understood by the reader.	I don't understand the question	Government of France	Ministère de la Transition écologique et solidaire	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
30723	30	21	30	21	From the reference of IRENA(2019), it shows that the average cost of off-shroe wind is 0.115 USD/kWh(2019) as in p.75, Figure 4.1. On the other hand, floating offshore wind is 0.14 USD/kWh as in p.87, Figure 4.2.Therefore the word "economic" should be deleted.	Accepted. The text has been revised.	Government of Japan	Climate Change Division - Ministry of Foreign Affairs	Japan
78499	30	21	30	21	Floating wind farms offer economic … Reference needed. In Japan floating wind farms were found to be to expensive and not economicaly viable.	Accepted. The text has been revised.	Tomaž Žagar	Faculty for Energy Technology, University of Maribor	Slovenia
86515	30	21	30	24	Floating wind farms offer other benefits over fixed type wind farms such as having less obstacle over conflics of vast interest groups in the coastal and the land area due to remoteness and proving much more consistent energy outputs compared to those in the coastal areas due to being in a more windy area. Floaitng wind farm could be a key technolgy to achieve net zero emission by 2050 since it's capacity for largest deployment.	Rejected due to space limitations.	Kim Yong Yook	KIT Valley Inc.	Republic of Korea
79601	30	23			add " and in deeper water" after further offshore, because it is the depth which mainly make the sea condition, leaving aside the protection by littoral configuration.	Accepted. The text has been revised.	Marc Daras	CentraleSupelecAlumni	France
5347	30	25	30	27	Onshore wind turbines may have reached in some places a capacity factor as hihg as 36%. References? Where? The average capacity factor is rather close to 25% for onshore and around 40% for offshore turbines.	Accepted. IRENA 2021 report is now explicitly cited.	Michel SIMON	Retraité/ Pdt d'association	France
50203	30	25	30	25	It should be Figure 6.11	Accepted. The text has been revised.	Rishikesh Joshi	TU Delft	Netherlands
76399	30	25	30	31	Discussions around wind capacity factors are somwhat meaningless if the issue of variability is not addressed. Two wind farms with say a 30% capacity factor could have vastly different variabilities both on a weekly, monthly or seasonal basis. The degree of variablity has a direct impact upon the costs of transmission, storage, anciliary servives and the potential for curtailment. Additionally, the scale of variability and ramp rates will determine the costs of backup energy generators.	Rejected due to space limitations in this section. The issue of electricity transmission is discussed in section 6.4.3.	Robert Parker	Nuclear for Climate Australia	Australia
69505	30	29	30	30	The turbines that have smaller generators and smaller specific capacity per rotor area are the turbines for low wind speed areas, not the ones for windy sites!	Rejected. However, the sentence was confusing and it has been reformulated. The objective is to reach more equivalent full load hour in windy sites.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
71581	30	30	30	31	The conclusion does not fit the paragraph	Accepted. The text has been revised.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium

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85489	30	31	30	31	I would like to advocate for adding airborne wind energy (AWE) here. (overview: http://dx.doi.org/10.1016/j.rser.2015.07.053). It uses tethered planes or kites and can reach more abundant wind at higher altitudes while incurring less of a nimby effect. Although the technology is not yet commercially available it already works well at smaller scale. Because it uses much less material then conventional wind, it is potentially cheaper and easier to transport to hard to reach areas. Because it can use wind at higher altitudes it can also be deployed where wind surface conditions are not good enough for regular wind turbines, which makes much more wind practically available (see e.g. https://doi.org/10.1016/j.renene.2019.03.118). I could imagine adding some text along the lines of: "Airborne wind energy (http://dx.doi.org/10.1016/j.rser.2015.07.053) is another wind technology that might have advantages in certain circumstances. The absence of a tower makes it easier to use in deep water and because it can reach higher it might be attractive where there is not enough wind close to the ground (https://doi.org/10.1016/j.renene.2019.03.118). Since it uses less materials it is easier to transport to remote locations.	Rejected due to space limitations.	Auke Hoekstra	Eindhoven University of Technology	Netherlands
28419	30	35	30	35	Airborne wind energy could be added as promising new technology in this area. AWE is an innovative wind energy technology which uses tethered kites to access the high altitude wind resource which is currently inaccessible by conventional wind turbines. The main advantages over similar sized conventional wind turbines is - Higher and adjustable operating altitudes which will lead to higher utilization factors. This makes them more suitable for far offshore, off-grid and remote locations, and bring them closer to a 'baseload' technology reducing storage requirements in highly renewable energy systems. Relevant sources are: 1. Cherubini, A., Papini, A., Vertechy, R., & Fontana, M. (2015). Airborne Wind Energy Systems: A review of the technologies. Renewable and Sustainable Energy Reviews, 51, 1461–1476. https://doi.org/10.1016/j.rser.2015.07.053 2. Airborne Wind Energy. (2013). In R. Schmehl (Ed.). https://www-springer-com.tudelft.idm.oclc.org/gp/book/9783642399640 3. Airborne Wind Energy: Advances in Technology Development and Research. (2018). In R. Schmehl (Ed.). Springer. https://www-springer-com.tudelft.idm.oclc.org/gp/book/9789811019463	Please refer to response to nearly identical comment 85489.	Naud Loomans	Eindhoven University of Technology	Netherlands

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
50205	30	35	30	35	The paragraph is talking about technological developments in wind energy and hence I think AR6 would be a perfect medium for introducing airborne wind energy (AWE) to the world. The report already has noteworthy mentions about innovative technologies in other energy systems like the thin film solar cells in the solar energy section. Therefore, it would definitely make sense to introduce AWE in the wind energy section! AWE is an innovative wind energy technology which uses tethered kites to access the high altitude wind resource which is currently inaccessible by conventional wind turbines. Research on AWE has been accelerated in the last two decades, and currently 40+ instituitions around the world are involved in the research and development of the technology. Once matured, an AWE system will cost much lower than a similar sized conventional wind turbine. The main advantages over similar sized conventional wind turbines are - It has higher and adjustable operating altitude which will lead to higher utilization factors. Low wind speed locations which are not suitable for wind turbines could be suitable for AWE systems. It uses lesser material and smaller foundation which will lead to lesser capital costs and lower carbon footprint. This inturn makes it more suitable for far offshore, off-grid and remote locations. Some of the key challenges of the technology are - It is highly dependent on the cutting edge research on materials and control systems. There exists regulatory barriers which are not yet clear to the AWE developers. There is no convergence in the AWE concept and hence a barrier for development of a supply chain for the industry. Few starting points for literature on AWE: 1. Cherubini, A., Papini, A., Vertechy, R., & Fontana, M. (2015). Airborne Wind Energy Systems: A review of the technologies. Renewable and Sustainable Energy Reviews, 51, 1461–1476. https://doi.org/10.1016/j.rser.2015.07.053 2. Airborne Wind Energy. (2013). In R. Schmehl (Ed.). https://www-springer-	Please refer to response to nearly identical comment 85489.	Rishikesh Joshi	TU Delft	Netherlands
75643	30	35	30	35	This piece would benefit from adding airborne wind energy as a potentially high-impact, innovative technology. AWE makes use of tethered kites to gain access to a high altitude wind resource; currently inaccessibly by conventional wind turbines. The main advantages include the higher and adjustable operating altitudes which allows higher utilization. In essence, this makes AWE more suitable for further away offshore, off-grid and remote locations & makes them closer to a 'baseload' technology that would reduce storage requirements in highly renewable energy systems. Possible references for you to use are as follows: I.Cherubini, A., Papini, A., Vertechy, R., & Fontana, M. (2015). Airborne Wind Energy Systems: A review of the technologies. Renewable and Sustainable Energy Reviews, 51, 1461–1476. https://doi.org/10.1016/j.rser.2015.07.053 II.Airborne Wind Energy. (2013). In R. Schmehl (Ed.). https://www-springer-com.tudelft.idm.oclc.org/gp/book/9783642399640 III.Airborne Wind Energy: Advances in Technology Development and Research. (2018). In R. Schmehl (Ed.). Springer. https://www-springer-com.tudelft.idm.oclc.org/gp/book/9789811019463	Please refer to response to nearly identical comment 85489.	Amira El-Feiaz	Technische Universiteit Eindhoven	Netherlands

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
84999	30	35	31	2	This section could clarify the benefits and penetration potential of AWE in the existing power grid. It could, for instance, mention that AWE can be more suitable for further away offshore, off-grid and remote locations, making it closer to a 'baseload' technology that would reduce storage requirements in highly renewable energy systems. This is highly important if we want to increase the share of renewables in the power system while maintaing its reliability and security of supply.	Please refer to response to nearly identical comment 85489.	Sofia Rosero Abad	University	Netherlands
6037	30				A 164 m rotor sounds like a lot of material. Are turbine materials recyclable? If so, how much does it cost to recycle the materials?	Taken into account. See response to comment 75747.	Adam Burak	University of Michigan	United States of America
5349	31	3	31	8	You are comparing figures which ar not comparable : How do you include the cost of intermitence? How do you evaluate the effects of commercialisation practice (priority access to the grid)? How do you take into account the diffrences in taxes system appliend ti the diffrent sources? Why don't you mention the level of public subsidies?? Etc. In no case, you can write : Onshore wind is now consistently undercutting fossil fuels and hide the fact that the figures are not comaparable. IPCC must be impartial and vigilant on the accuracy of the statements.	Rejected. Further down the text a caveat of the cost of integration is added.	Michel SIMON	Retraité/ Pdt d'association	France
55651	31	3	31	8	Why were these countries selected for inclusion in this section? Are they meant to represent a range of wind markets to show that LCOE is lower than fossil fuel-fired options across a spectrum or are they the lowest examples?	Taken into account. The text has been modified not to single out any countries	Government of United States of America	U.S. Department of State	United States of America
71583	31	3	31	7	Why are these (and not other) countries explicitely mentioned?	Taken into account. The text has been modified not to single out any countries	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
84309	31	3	31	8	Effective costs are dependent of the final quality required by the grid, actually given by dispatchable sources, i.e. additional costs have to be included for variables sources. Besides connection to the transmission grid entails also over-costs which could be very high for off-shore wind farm. At last, wind potential is decreasing with the level of implementation. Despite of a decreasing LCOE, competiveness of wind sources is not obvious.	Rejected. Further down the text a caveat of the cost of integration is added.	Vincent MAZAURIC	Schneider Electric	France
79603	31	4	31	8	the reference to fossil fuel power plant in Argentina is improper to compare with wind farm all over the world.	Accepted. The text has been revised.	Marc Daras	CentraleSupelecAlumni	France
52179	31	5	31	5	The comparison with Argentina might not be relevant here.	Accepted. The text has been revised.	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
10929	31	6	31	8	change the metric from KWh to MWh since the main metric is MWh	Rejected. The commonly accepted unit of LCOE is USD/kWh	Dong-Woon NOH	Korea Energy Economics Institute	Republic of Korea
16353	31	6	31	8	change the metric from KWh to MWh since the main metric is MWh	Please refer to response to nearly identical comment 16353.	Government of Republic of Korea	Korea Meteorological Administration (KMA)	Republic of Korea
48595	31	22	31	24	Vertical axis for LCOE should re $/kWh [not $/kW].	Accepted. The figures have been redrawn.	Karl Hausker	World Resources Institute	United States of America
3175	31	23	31	23	Figure 6.11: unclear whether the capacity factors and LCOE are for windmills installed in the considered year, or for the windmills in operation this year. Same remark for Figure 6.16 in this chapter.	Accepted. The fiigure caption has been clarified.	Philippe Quirion	CNRS	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
7859	31	23	31	23	Right hand Figure in multpanel 6.11 needs y-axis units inUSD/kWh rather than USD/kW	Accepted. The figures have been redrawn.	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
7861	31	23	31	23	Moreover, when carbon-rich fuel end-products are combusted, significant proportions of CO2 get emitted back into the atmosphere -- this would be a good time to promote that any CCU route requires a full life cycle analysis to understand the GHG benefit, particularly if products have a short lifetime e.g. CCU fuels. It might also be helpful to point out that products made from CCU is unlikely to be a replacement for CCS, they are different approaches. This was one of the conclusions from the ducument - Actions required to develop a roadmap towards a Carbon Dioxide Utilisation Strategy for Scotland (I am the lead author) It is not a helpful outcome if an impression is given that CCU and CCS are interchangeable - as for scale and mitigation - CCS is required. The terminology becomes blurred however with Enhanced Oil Recovery - as this is promoted as CCU - but there is an argument it should be viewed as CCS. Again - the lifecycle of EOR is something that needs carefully examined. (http://www.evaluationsonline.org.uk/evaluations/Search.do?ui=basic&action=showPromoted&id=606#:~:text=Scottish%20Enterprise%20(SE)%20commissioned%20this%20report%20to%20better,explore%20and%20develop%20its%20potential%20in%20this%20area.)	Noted but the commemt seems out of place.	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
45481	31	23	31	24	What does the range in the figures indicate? E.g. full range, percentiles, or?	Accepted. The fiigure caption has been clarified.	Kornelis Blok	Delft University of Technology	Netherlands
45483	31	23	31	24	Costs of offshore wind quoted by IRENA seem quite high. But there may be reginal differentiation. In the NL already in 2018 they were ranging from 0.06 - 0.08 Euro/kWh (incl. grid connection). Here is the source from the Neth Env. Assessment Agency (PBL): https://www.pbl.nl/sites/default/files/downloads/pbl-2019-costs-of-offshore-wind-energy-2018_3623.pdf.	Rejected. The IPCC assessment is based on published literature.	Kornelis Blok	Delft University of Technology	Netherlands
20937	31	25	31	26	It seems unclear: why the capacity factor of offshore wind turbines decrease sharply in 2014 ?	Several offshore wind farms in relatively windy locations were commissioned in 2013 (generators from 3-6 MW), only 3 wind farms in 2014 with smaller generators (3 MW).	Government of France	Ministère de la Transition écologique et solidaire	France
20939	31	25	31	25	There is a mistake on the labelling of the right most figures. Unit of LCOE is USD/kWh, not USD/kW	Accepted. The figures have been redrawn.	Government of France	Ministère de la Transition écologique et solidaire	France
84311	31	28	32	5	The issue of tension on functional/structural materials is not adressed regarding the dilution of wind assets. It concerns: Rare Earth magnets for rotor, copper for grid connection, Gallium for large gap semi-conductors… iron and cement!	Taken into account. A new box on rare earth elements and critical metals has been added.	Vincent MAZAURIC	Schneider Electric	France
79777	31	30	32	32	One significant environmental impact from the composite materials. This issue is not yet solved and there are already many related publications addressing this. E.g. https://doi.org/10.1007/s40831-020-00313-3, https://doi.org/10.3390/recycling4010007, https://doi.org/10.1016/j.compositesb.2021.108768	Taken into account. See response to comment 75747.	Constantinos Psomopoulos	University of West Attica, Department of Electrical and Electronics Engineering	Greece

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
20941	32	2	32	4	Maybe more important for offshore electricity farms than for onshore ones	Rejected. The reference cited indicates that "On-shore and offshore turbines can have similar emission factors because larger emissions during the construction phase of offshore turbines can be compensated by their higher efficiency during use."	Government of France	Ministère de la Transition écologique et solidaire	France
20943	32	4	32	5	The carbon footprint of offshore wind could be further reduced with the development of ever more powerful offshore wind turbines. https://www.sciencedirect.com/science/article/pii/S0960148117301258	Taken into account. The new reference has been added.	Government of France	Ministère de la Transition écologique et solidaire	France
61211	32	6	32	15	adding the assessment on the impact on biodiversity, as well as on soil pollution and water pollution	Rejected due to lack of available space in the section.	Jianguo WU	chinese research academy of environmental sciences	China
18227	32	9	32	9	(Section 6.4.2.2) "The impacts on animal habitats and collisions can be resolved or reduced through selective stopping program…". This is a little hard to follow. Perhaps worth including a short explanation of what is meant by 'selective stopping programme'.	Accepted. The text has been clarified.	Government of United Kingdom (of Great Britain and Northern Ireland)	Department for Business, Energy & Industrial Strategy	United Kingdom (of Great Britain and Northern Ireland)
55653	32	9	32	9	Explain what a selective stopping program is, e.g., stopping wind turbine blades during periods when there is a high probability of bird/bat collisions, etc.	Accepted. The text has been clarified.	Government of United States of America	U.S. Department of State	United States of America
64399	32	10	32	12	When discussing wind energy curtailment to address impacts to wildlife, the authors should note increased cut in speeds that are implemented to address bat mortality. It would also be helpful to introduce the concept of "Activity-based Informed Curtailment." The authors also suggest that curtailment to address wildlife concerns does not affect productivity of the wind farm, but this isn't accurate. The impact on productivity depends on the specific conditions and concerns at the site, but it is measurable and is of concern to wind farm owners and operators because it decreases facility revenue.	Accepted. The text has been clarified.	Curt Bjurlin	Stantec Consulting	United States of America
9161	32	12	32	13	Please adress the cumulative impacts of large development of offshore wind farms projects onthe biodiversity.	Rejected due to lack of available space in the section.	Marin Constantin	RATEN ICN	Romania
20945	32	12	32	13	The impact of floating wind turbine foundations has already been mentioned on page 30, lines 22, 23, 24. However, this remark is incomplete. The environmental impacts are different depending on the foundations and the whole life of the project has to be considered. https://www.boem.gov/sites/default/files/documents/environment/Wind-Turbine-Foundations-White%20Paper-Final-White-Paper.pdf	Accepted. The text has been clarified.	Government of France	Ministère de la Transition écologique et solidaire	France
20947	32	12	32	13	A large development of offshore wind farm must consider the cumulative impacts of projects on biodiversity. M. Wing Goodale & Anita Milman (2016) Cumulative adverse effects of offshore wind energy development on wildlife, Journal of Environmental Planning and Management, 59:1, 1-21, DOI: 10.1080/09640568.2014.973483 https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwiln7vyk9PuAhWCyoUKHe3pAccQFjAQegQIHhAC&url=http%3A%2F%2Fwww.edc.uri.edu%2Fnrs%2Fclasses%2Fnrs555%2Fassets%2Freadings_2017%2FGoodale_Milman_2016_JEnvPlanningManagement.pdf&usg=AOvVaw0HqyGtV6RqnPOKZyW7H3Dt	Accepted. The text has been clarified.	Government of France	Ministère de la Transition écologique et solidaire	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
31457	32	12	32	13	A large development of offshore wind farm should include the impac on biodiversity	Accepted. The text has been clarified.	Carolina Ahnert	Universidad Politécnica de Madrid	Spain
51073	32	12	32	13	“Offshore wind farms can also impact migratory birds and other sea species (Hooper et al. 2017)”: Not only! More generally, a large development of offshore wind farms must consider the cumulative impacts of projects on biodiversity [1]. [1] M. Wing Goodale & Anita Milman (2016) Cumulative adverse effects of offshore wind energy development on wildlife, Journal of Environmental Planning and Management, 59:1, 1-21, DOI: 10.1080/09640568.2014.973483 A large development of offshore wind farm must consider the cumulative impacts of projects on biodiversity.	Please refer to response to identical comment 20947	Eric PROUST	European Nuclear Society (ENS)	France
10637	32	14	32	15	This sentence goes definitely beyond the carefully worded conclusions reached by Poulsen et al.	Accepted. The text has been revised.	Philippe Waldteufel	CNRS	France
45883	32	14	32	14	Consider changing sentence to : "The impacts of wind farm noise on long-term human and terrestrial mammals health have been shown to be well below detectable levels (Helldin et al. 2012; Poulsen et al. 2018)." Helldin, J. O., J. Jung, W. Neumann, M. Olsson, A. Skarin and F. Widemo, 2012. The impacts of wind power on terrestrial mammals: A synthesis. The Swedish Environmental Protection Agency. Source: http://naturvardsverket.se/Documents/publikationer6400/978-91-620-6510-2.pdf	Accepted. The text has been revised.	Government of Germany	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety International Climate Policy	Germany
64401	32	14	32	14	The authors suggest that there is no effect of wind farm noise on long-term human health, but this statement is perhaps too binary and does not address shadow flicker and the movement introduced to the landscape associated with the rotor. Some people who live among wind turbines do not feel comfortable and struggle to acclimate to the change to the landscape. While proponents of wind energy development see the broader benefits, it is important to also recognize the impacts to the sense of well-being of a sub-group of impacted people. This can sometimes be an environmental justice issue, because not all affected populations reap the financial rewards of the development and it is not uncommon for small-holding residential owners within the footprint of a wind energy facility to receive no financial benefit at all.	Partially accepted. The text has been revised, but further comments cannot be added due to space limitations.	Curt Bjurlin	Stantec Consulting	United States of America
74849	32	15	32	15	There is need to also include the impact of wind farms on telecommunication signals. This is missing yet an important component to be noted.	Rejected due to lack of available space in the section.	Government of Kenya	Kenya Meteorological Service	Kenya
9163	32	16	32	17	"high support" is not an appropriate term, it is too general applied. Please ammend it "in some/many cases there is a high support according with the references…"	Accepted. Rephrased as Public support for onshore and particularly offshore wind energy is generally high	Marin Constantin	RATEN ICN	Romania
9507	32	16	32	27	The point about 'threaten areas of symbolic values' (Devine-Wright, 2005) is ambiguous. I suggest you substitute the word 'places' for 'areas' since it is closer to the key concepts of sense of place and place attachment used in the literature. More recent studies than 2005 could also be cited here, including Russell et al (2020): https://doi.org/10.1016/j.rser.2020.110044 and Devine-Wright and Wiersma (2019): https://doi.org/10.1016/j.enpol.2019.111086.	Accepted, we replaced the text 'threaten areas of symbolic values (Devine-Wright 2005)' with 'threaten places of symbolic vaules, and included the two recent references suggested	Patrick Devine-Wright	University of Exeter	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
9511	32	16	32	27	This section refers to public acceptability in a general way when research on 'social acceptance' (Devine-Wright et al., 2017 - http://dx.doi.org/10.1016/j.enpol.2017.04.020) distinguishes between socio-cultural and local community levels of analysis. In doing so, by separating out general public attitudes or beliefs about wind power from local community responses to particular projects, this would add clarity to this section.	Noted, this is acknowledged in the first sentence of this section. Moreover, we explicate when we refer to local responses	Patrick Devine-Wright	University of Exeter	United Kingdom (of Great Britain and Northern Ireland)
20949	32	16	32	17	It would be interesting to have the impacts of windfarm noise on marine biodiversity as it is sometimes studied for land biodiversity	Noted	Government of France	Ministère de la Transition écologique et solidaire	France
51075	32	16	32	17	"high support for onshore": too general. Support by who? It should be indicated. Obviously not by local populations	accepted, rephrased as Public support for onshore and particularly offshore wind energy is generally high	Eric PROUST	European Nuclear Society (ENS)	France
79605	32	18	32	19	The use "believe" seems inappropriate, notably in second sentence, because the visual impact can be experimented. 'Consider" might be a better choice.	Noted, we refer to believe to indicate that this is a subjective judgement.	Marc Daras	CentraleSupelecAlumni	France
10639	32	19	32	20	Admittedly some people believe noise effect exists; on the other hand concerning esthetics it is not a belief, it is an opinion.	Noted, belief refers to a subjective judgement indeed	Philippe Waldteufel	CNRS	France
64403	32	19	32	22	the authors state "some people believe…" and then list a number of known and documented impacts. This sentence suggests that these beliefs are unsubstantiated or debated, but it is well-document that wind turbines cause a change to ambient noise, change the visual aesthetic, have impacts to areas of symbolic values, etc. Instead of suggesting these are beliefs, it would be more genuine for the authors to recognize these are the impacts associated with this technology and that would need to be assessed and mitigated to the extent practicable. I understand that this section is intended to be about beliefs, but the way the write-up is drafted makes me feel that the authors are not giving enough of a discussion on the limitations.	Noted. This paragraph discusses which factors affect the level of public support for wind energy, and which beliefs affect support. We refer to beliefs, as people differ in the extent to which they acknowledge the consequences, and these differences affect the level of public support.	Curt Bjurlin	Stantec Consulting	United States of America
64405	32	22	32	23	Many wind energy developments are built in areas or regions that have never had electricity generation facilities (wind turbines are often sited on high ground, while fossil fuel generation is typically associated with water sources and therefore sited at lower areas). Communities receiving wind turbines are often producing electricity for the very first time and as such grapple with the tradeoffs between environmental benefits, increased revenue in the community, and the substantial change to the aesthetic that comes with a utility-scale facility.	Noted. We did not find studies on public acceptability of such projects	Curt Bjurlin	Stantec Consulting	United States of America
20951	32	24	32	25	Introducing the alternative ways to gain local support would be relevant. i.e: Ellis and Ferraro (2016), The social acceptance of wind energy; EUR 28182 EN, doi 10.2789/696070	Accepted. We added the sentence: public support may increase by targeting these factors. after the sentence Public acceptability of local wind projects is higher when people believe fair decision-making procedures have been implemented (Aitken 2010a; Dietz and Stern 2008).	Government of France	Ministère de la Transition écologique et solidaire	France
64159	32	24	32	25	Silva Herran et al. (2016 Energy Policy) provides global estimates of the reduction in onshore wind energy potential due to visibility restrictions.	Noted. The issue has not been included due to space limitations.	Diego Silva Herran	National Insititute for Environmental Studies	Japan
9509	32	25	32	25	The word 'compensation' is used in the text, but it does not describe the provision of in-kind and financial benefits in contexts where no negative impact is accepted by developers or obliged by government regulation. For example, Rudolph et al (2018 - DOI: 10.1177/2399654417699206) and Cass et al (2010 - DOI: 10.1080/1523908X.2010.509558) both refer to the multiple ways that companies avoid compensation language and instead choose alternative discourse for benefit provision, and to avoid accusations of bribery. These insights about 'benefit provision' could be more clearly reflected here.	Accepted. The references are used, but because of lack of space, no further explanation is given.	Patrick Devine-Wright	University of Exeter	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
20953	32	26	32	26	So high support for onshore (first sentence) and even higher for offshore ? This appears very optimistic	Noted, public support for wind energy is generally high indeed, but support can be lower for specific projects, as indicated	Government of France	Ministère de la Transition écologique et solidaire	France
55655	32	27	32	29	Sentence includes duplicative mentions of high upfront capital costs.	Accepted. The text has been revised.	Government of United States of America	U.S. Department of State	United States of America
20955	32	29	32	32	Also right pricing and market architecture	Not sure of what this means?	Government of France	Ministère de la Transition écologique et solidaire	France
17345	32	33	32	33	Solar energy and Wind energy chapters should be followed by "electricity storage" chapter. Wind and solar PV will stand and fall with availability of economic storage.	Noted.	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
18229	32	33	34	34	(Section 6.4.2.3) This section would benefit from a fuller discussion of the impacts of hydropower in terms of water stress / drought, the outcomes of those impacts for biodiversity, ecosystems and human livelihoods, and the climate implications (in turn) of those biodiversity and ecosystem-level water-stress effects. For example, reducing water availability downstream has implications for vegetation (and the biodiversity and humans that depend on it), which in turn (especially in forested areas) has implications for local climate (rainfall and temperature control) and CO2 sequestration. Discussion of such impacts and trade-offs should be included.	Rejected due to lack of available space in the section.	Government of United Kingdom (of Great Britain and Northern Ireland)	Department for Business, Energy & Industrial Strategy	United Kingdom (of Great Britain and Northern Ireland)
20957	32	33	32	33	Why isn't the circular economy aspect developped ? There are growing concerns on the recycling of blades, sometimes burried in cemeteries	Rejected due to lack of available space in the section.	Government of France	Ministère de la Transition écologique et solidaire	France
20959	32	33	32	33	It is somewhat surprising that this section never mentions the risk of accidents with a large loss of life. Indeed, the failure of dams have caused a loss of life far greater than those of the nuclear accidents that are mentioned in the next section	Taken into account. Dam failure is now mentioned in the section	Government of France	Ministère de la Transition écologique et solidaire	France
71585	32	33	34	37	Hydropower in Europe (esp. on the Balkans) faces serious acceptance issues due to very valid environmental concerns. This should be added to the text. In general, in my opinion, the role of the environmental impact of hydropower could be elaborated more - currently many sentences sound as if people perceive that there are problems but these are not real (which I think is not correct).	We have a whole paragarph on the environmental and social impacts with constructing hydropower dams and another full paragarph on the social acceptance issue.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
29887	32	34	32	37	Consider to add more information about the role and potential use of hydropower infrastucture e.g. by mentioning that Hydopower is by far the largest source of renewable electricity worldwide, and the possibility to utilize such infrastucture as an adaptation measure such as environmental flows. Since this is a well acknowledged feature of sustainable hydropower development and operation. See https://ec.europa.eu/environment/water/water-framework/facts_figures/guidance_docs_en.htm and the IHA sustianability protocol	Taken into account. We have added a phrase about the fact that hydro is the largest source of renewable electricity globally.	Government of Norway	Norwegian Environment Agency	Norway
55657	32	34	32	34	Change text to: "… is used for primary power and may be used to balance …"	Accepted, but revised somewhat differently from the suggested text.	Government of United States of America	U.S. Department of State	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
76581	32	34	32	37	There is a lot of potential for refurbishment of old hydro power plants and this should be in focus to tackle climate change. By replacing the turbine runners, renew turbine parts, implementing modern control systems a lot of improvement of old hydro power plants concerning efficiencies and operating ranges is possible.	Rejected due to lack of available space in the section.	Armin Winkler	University of Applied Sciences Upper Austria	Austria
77343	32	34	32	34	Rewrite sentence to "Hydropower is technically mature, proved worldwide and may be used to balance electricity supply, provide flexibility and storage, as well as a number of other services (flood control, water supply, irrigation, etc) - in addition to renewable energy"	Accepted, but revised somewhat differently from the suggested text.	Atle Harby	SINTEF Energy Research	Norway
61559	32	35	32	35	EU study on energy subsidies 2019 also worth citing https://ec.europa.eu/energy/studies/study-energy-prices-costs-and-subsidies-and-their-impact-industry-and-households_en	Rejected. Not a relevant reference to the content of this particular paragraph	tom howes	International Energy Agency	France
77353	32	35	32	37	Rewrite sentence to "Areas for improvement are to be found mostly during the planning of a hydropower plant to minimise environmental and social impacts, and to modernise hydropower to increase generation capacity and flexbility to better integrate variable renewables over multiple time periods." It is very important to modernise the ageing hydropower fleet to meet new requirements, and this must be emphasized in this report. The text about "coordination at long distances" is very unclear, what is the meaning of this? It is much more important to coordinate hydropower with wind and solar power, as well as batteries. Hydropower that can have flexibility in generation and storage ranging from mili-seconds to seaons should be used for that in combination with wind, solar and short-term storage (batteries) - in addition to be generating renwable energy (it is still the largest renewable resource)	Accepted, but revised somewhat differently from the suggested text.	Atle Harby	SINTEF Energy Research	Norway
967	32	38			PW h or PW(middledot)h or PW-h	Rejected. PWh is wildelly used.	Alok Dhaundiyal	Szent Istvan University	Hungary
17497	32	38	32	38	Can you elaborate on the difference between "theoretical available hydropower potential" and technical potential? Thanks	Rejected due to lack of available space in the section, and because the the terms are commonly used in the literature.	Alaa Al Khourdajie	IPCC	United Kingdom (of Great Britain and Northern Ireland)
43567	32	38	32	48	Are estimates of thechnical and economic potential consistent with gross theoretical potential since sources are different?	Noted.	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy
55659	32	38	33	2	This section describes technical and economic potential for hydropower, plus the percentage it contributes to global electricity, but how much energy does currently installed hydropower provide? The inclusion of this value will provide valuable context for the potential values.	Accepted.	Government of United States of America	U.S. Department of State	United States of America
969	32	40			Hoes et al. (2017) estimates (not clear) Hoes et al.'s (2017) paper estimates or Hoes et al. (2017) estimate.	Accepted	Alok Dhaundiyal	Szent Istvan University	Hungary

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
4571	32	40	32	42	The main text gives the result interval of the hydropower theoretical reserves assessment and the 2017 research data, and it is recommended to add the 2020 research conclusion. Suggestion: "(BP, 2020)" is modified as "(BP, 2020). The assessment of the global hydropower resource is evaluated in 2020, with a total theoretical potential of 46.2 PWh yr-1.(GEIDCO,2020)" Reference: GEIDCO,2020: Global Energy Interconnection Development and Cooperation Organization. Research on Global Renewable Energy Development and Investment. Beijing : China Electric Power Press.	Rejected due to lack of available space in the section to add another sentence on the same point.	Shining Zhang	GEIDCO	China
971	32	41		42	one-tenth	Text removed.	Alok Dhaundiyal	Szent Istvan University	Hungary
2645	32	41	32	43	Why is the comparison to primary energy useful here? Primary energy can be misleading when comparing renewable and fossil generators, due to the substantially differing efficiencies. At a fixed amount of electricity consumption, primary energy drops when renewables increase their market share.	Accepted. Changed to be in term of global electricity production.	Jan Wohland	ETH Zurich	Switzerland
45485	32	41	32	42	Why compare with the total primary energy and not with electricity production, as is done in the next sentence (and is also more logical).	Accepted. Changed to be in term of global electricity production.	Kornelis Blok	Delft University of Technology	Netherlands
29889	32	42	32	48	Please include findings found in https://hydropower-assets.s3.eu-west-2.amazonaws.com/publications-docs/2020_hydropower_status_report.pdf in your assessment. In that report it is stated that Africa has the highest percentage of untapped technical hydropower potential in the world, with only 11 % utilised by 2019. Please check this for consistency with your assessment.	Taken into account. Notice that the suggested report states that Africa has the highest untapped hydropower potential. The IPCC text refers solely to the hydropower potential.	Government of Norway	Norwegian Environment Agency	Norway
973	32	44			remove article before signifcance	Rejected. Original phrase is correct.	Alok Dhaundiyal	Szent Istvan University	Hungary
2647	32	45	33	2	It is not really clear what an "economic potential" is (current cost assumptions, future, learning?) and how exactly if differs from an available potential.	Rejected. Term is commonly used in the literature	Jan Wohland	ETH Zurich	Switzerland
975	32	46			economic (remove article)	Rejected. Original phrase is correct.	Alok Dhaundiyal	Szent Istvan University	Hungary
42979	32	46	32	46	Technical and economic potential are not defined and likely not intuitive for a general audience	Rejected. Terms are commonly used in the literature	Kurt Kornelsen	Ontario Power Generation	Canada
17809	32	47	32	48	Highly recommend to change this phrase "The greatest contributor to the hydropower potential is Asia (48%), followed by S. America (19%) (Hoeas at al. 2017)" to more recent and exact info on countries' potential, e.g. thus mentioning China, Russia, Canada, DRC, US, etc., at least top-10 OR e.g. According to Key World Energy Ststistics 2019 based on 2017 data the Top 5 Producers of Hydroelectricity are China (1190 TWh), Canada (393 TWh), Brazil (371 TWh), USA (325 TWh) and Russia (187 TWh).	Rejected. Incomplete info about suggested new data source. Accroding to Hoes et al. (2017), the largest potentials are China (7,168 TWh), Brazil (3,630 TWh), Russia (3,503 TWh), Canada (3,064), and the United States (2,564 TWh). But we kept the details at the continental level due to the lack of available space in this section.	Sergey Chestnoy	UC RUSAL	Russian Federation
19907	32	47	32	48	Highly recommend to change this phrase "The greatest contributor to the hydropower potential is Asia (48%), followed by S. America (19%) (Hoeas at al. 2017)" to more recent and exact info on countries' potential, e.g. thus mentioning China, Russia, Canada, DRC, US, etc., at least top-10 OR e.g. According to Key World Energy Ststistics 2019 based on 2017 data the Top 5 Producers of Hydroelectricity are China (1190 TWh), Canada (393 TWh), Brazil (371 TWh), USA (325 TWh) and Russia (187 TWh).	Rejected. Incomplete info about suggested new data source. Accroding to Hoes et al. (2017), the largest potentials are China (7,168 TWh), Brazil (3,630 TWh), Russia (3,503 TWh), Canada (3,064), and the United States (2,564 TWh). But we kept the details at the continental level due to the lack of available space in this section.	Yulia Dolinina	UC RUSAL	Russian Federation

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977	33	1	34	37	Hydroelectric power also has demerits (In summer, water shortage crops up). As glaciers are shifting, so it won't be viable in the future. Add some shortcomings. Moreover, the sesmic prone zones (Himalayan belt) do not support such plants.	Rejected due to lack of available space in the section	Alok Dhaundiyal	Szent Istvan University	Hungary
45487	33	3	33	5	The unit in the picture seems not correct: It seems that it must be something like GWh m-1 yr-1 (in one or the other way, the area needs to come into play)	Rejected. The unit is consistent with the info provided in Hoes et al. (2017).	Kornelis Blok	Delft University of Technology	Netherlands
77355	33	3	34	2	This sentence is valid for all renewable technologies. They all have serious challenges with environmental and social impacts as well as sustainability issues. Such sentences must be inserted for all technolgies, there are of course not possible to build anything in the nature without impacting it. However, there are also many very good examples of how this is solved for hydropower as well as for others.	Rejected. It is necessary to mention the environmental and social impacts of hydropower in this section. Plus, the comment refers to an entire page and not a single sentence.	Atle Harby	SINTEF Energy Research	Norway
76583	33	7	33	8	The peak efficiency of hydroelectric plants in greater than 85%:	Accepted	Armin Winkler	University of Applied Sciences Upper Austria	Austria
17499	33	8	33	8	"typically"?	Accepted	Alaa Al Khourdajie	IPCC	United Kingdom (of Great Britain and Northern Ireland)
63159	33	10			"run off-river" should be corrected to "run-of-river"	Accepted	Jennifer Sklarew	George Mason University	United States of America
29891	33	11	33	12	Please consider including "more than" in front of "10 MWs.". E.g. in Norway we have several hydropower plants in large rivers that produce substantially more than 10 MW.	Accepted	Government of Norway	Norwegian Environment Agency	Norway
76585	33	11	33	12	It's not true that hydro power plants without storage can only produce up to10MW. There are many hydro powerplants without storage which have a higher electical output. For example river power plants along the Danube produce > 100 MW electical power.	Phrase deleted	Armin Winkler	University of Applied Sciences Upper Austria	Austria
77345	33	11	33	12	The sentence "Hydropower plants without or with small storage can produce a few kWs to 10 MWs" is completely wrong. Many hydropower plants without storage or with small storage produce several TWh per year. Please also notice that the wording is wrong as production is measured in kWh, MWh, GWh or TWh, not in kW or MW. kW and MW are measures of power, not energy. Delete the whole sentence, the production from a hydropower plant is not necessarily depending on the storage	Taken into account. Phrase deleted	Atle Harby	SINTEF Energy Research	Norway
77347	33	13	33	15	It is not possible to generalise in this way, and the sentence should be modified. There are many hydropower plants without its own storage that are not necessarily susceptible to climate variability, that depends on the location. It seems like the authors are not really familiar with hydropower	Phrase deleted	Atle Harby	SINTEF Energy Research	Norway
27721	33	16	33	23	The paragraph remains incomplete.	accepted. The phase has been modified	Eleni Kaditi	Organization of the Petroleum Exporting Countries, OPEC	Austria
30351	33	16	33	18	Consider to further specify this..."Such hydropower plants may require large dewatered ares for their reservoirs, but this is dependent on location (head) and environmentel restrictions;"	Rejected due to lack of available space in the section to add another sentence on the same point.	Government of Norway	Norwegian Environment Agency	Norway

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
77349	33	16	33	16	Generation are not measured in GW, but in GWh, MWh or TWh. The most important characteristics of a hydropower plant with large generation, is that it needs either a large flow or a high head, or both. The largest powe plants in the world are hydropower plants (7 of the 10 largest in installed capacity, 5 of the 10 largest in generation). I suggest to re-write this sentence to "Five of the world's largest power plants are hydropower plants, some of them with generation over 100 TWh per year and installed capacities above 10 GW"	Accepted. The unit in the text was corrected	Atle Harby	SINTEF Energy Research	Norway
73949	33	18	33	19	alternative form.. "increase reserve margins, reliability and security of supply of the electricity grid"	Accepted, but we went with the suggested edits in comment 73951	Heleno Miguel	Lawrence Berkeley National Laboratory	United States of America
73951	33	19	33	20	a more rigorous formulation of the sentence: "It can be used to compensate rapid variations of netload, and to supply the peak demand, decreasing the marginal costs of electricity"	Accepted. The sentence has been modified accordingly.	Heleno Miguel	Lawrence Berkeley National Laboratory	United States of America
28683	33	20	33	23	These sentences are not grammatical or complete.	Accepted. The sentences have been modified.	Asa Hopkins	Synapse Energy Economics	United States of America
61761	33	20	33	20	The reference (Jacobson et al, 2015, https://doi.org/10.1073/pnas.1510028112) is disputed, and one cause for that was especially how it claimed unrealistic abilities for hydro-reservoirs to produce much more peak power than their current turbine capacity would allow, which would also cause severe issues for the discussed water regulation. See the discussion in (Bistline and Blanford, 2016, https://doi.org/10.1073/pnas.1603072113) and the rebuttal in (Clack et al., 2017, https://doi.org/10.1073/pnas.1610381114). A more relevant reference should be used than one that has been disputed.	Accepted. Disputed reference deleted.	Rauli Partanen	Think Atom	Finland
65803	33	20	33	20	The reference (Jacobson et al, 2015, https://doi.org/10.1073/pnas.1510028112) is disputed, similarly as most of his other 100%RE work. See the discussion in (Bistline and Blanford, 2016, https://doi.org/10.1073/pnas.1603072113) and the rebuttal in (Clack et al., 2017, https://doi.org/10.1073/pnas.1610381114). There certainly exists more relevant references to tell the reader that a hydroreservoir can be used also for water regulation. Please, choose a better reference.	Accepted. Disputed reference deleted.	Eero Hirvijoki	Aalto University	Finland
17347	33	21	33	21	"...pumped storage hydropower store energy…" Pumped storage deservs a dedicated chapter (if batteries deserve one). It is much more mature and economic way for electricity storage today. Batteries will not surpass it in the next decade.	Rejcted due to lack of space in the chapter	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
17501	33	22	33	23	No clear: "The regulatory characteristics of the storage of the hydropower plants on 23 the electricity system can be experienced"	Accepted. The sentence has been modified.	Alaa Al Khourdajie	IPCC	United Kingdom (of Great Britain and Northern Ireland)
29517	33	22	33	23	The last sentence of the paragraph is either insufficient or unclearly written. Please consider to improve clarity, or drop the sentence. We believe for instance that "Regulatory" should be replaced with "Regulating", and that the sentence needs a proper ending.	Accepted. The sentence has been modified.	Government of Norway	Norwegian Environment Agency	Norway
43569	33	22	33	23	Broken, incomplete sentence.	Accepted. The sentence has been modified.	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy

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47043	33	22	33	23	This statement is unfinished.	Accepted. The sentence has been modified.	John Leo Algo	Living Laudato Si' Philippines	Philippines
52181	33	22	33	23	Not clear what "can be experienced" means.	Accepted. The sentence has been modified.	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
55661	33	22	33	23	This sentence is incomplete and, as such, the purpose cannot be determined.	Accepted. The sentence has been modified.	Government of United States of America	U.S. Department of State	United States of America
69507	33	22	33	22	Is the sentence complete?	Accepted. The sentence has been modified.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
55663	33	23	33	23	Something is missing after "experienced". This paragraph needs editing.	Accepted. The sentence has been modified.	Government of United States of America	U.S. Department of State	United States of America
63161	33	23			The sentence appears to be incomplete.	Accepted. The sentence has been modified.	Jennifer Sklarew	George Mason University	United States of America
29893	33	24	33	26	Please consider highlighting also that many hydropower projects also have the hightest energy payback ratios compared to most other energy sources, and can therefore also be seen as preferable in a LCA (Life Cycle Assessment) context .	Rejected due to lack of space.	Government of Norway	Norwegian Environment Agency	Norway
55665	33	24	33	24	This paragraph needs to start with the capital costs, then describe the O&M costs, and finally, if there is a basis for it, the sentence "Hydropower is one of the lowest-cost energy technologies" could be used at the end of the paragraph.	We prefer the current flow. A more recent citation was added to support the claim about being one of the cheapest.	Government of United States of America	U.S. Department of State	United States of America
25023	33	33	34	15	Political considerations are very important in Hyrdo power. Hydro is one of a few REs that have significant cross-border effects	Rejected due to lack of space. The political issue is mention, and there is not sufficient space to emphasize this aspect even more.	Bassam AbuHijleh	The British University in Dubai	United Arab Emirates
42981	33	33	34	1	You also mention potential benefits earlier such as recreation, water storage, etc. These benefits should also be weighed against costs.	Taken into account. As you stated, those were mentioned earlier in the section, but we added a sentence to remind the reader of the benefits and keep the tone more balanced.	Kurt Kornelsen	Ontario Power Generation	Canada
9165	34	3	34	15	Please introduce the risks of major accidents such as the dam failures (with catastrophic impact of population and environment	Taken into account. Se response to comment 20959	Marin Constantin	RATEN ICN	Romania
15097	34	3	34	15	Hydropower development has both advantages and disadvantages. Generally speaking, the advantages outweigh the disadvantages. However, the report overemphasizes that hydropower stations may have a serious impact on the environment and society, neglects the significant contribution of hydropower development to energy conservation and emission reduction, and hydropower development is also an important way and means to solve the contradiction between the growing demand for energy and energy conservation and emission reduction caused by social and economic development. It is suggested to add the expression in this respect.	Taken into account. See response to comment 42981	Guoquan HU	National Climate Center of China Meteorological Adminstration	China
29895	34	3	34	4	Consider adding..., both in the development and operational stage by emerging best mitigation measures (EU CIS guidance no 36 and 37 - https://ec.europa.eu/environment/water/water-framework/facts_figures/guidance_docs_en.htm)	Rejected due to lack of space. We don't have the space to drill down further on this, plus we prefer the current flow.	Government of Norway	Norwegian Environment Agency	Norway

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
31459	34	3	34	15	For consistency also mention the risks of catastrophic accidents due to dam failures	Taken into account. Se response to comment 20959	Carolina Ahnert	Universidad Politécnica de Madrid	Spain
43571	34	3	34	5	Some mitigating structures can be put in place to allow fish migration. see for instance https://circabc.europa.eu/sd/a/ac0769a7-1365-4902-9d03-f701a8afa190/Presentation-Measures%20to%20mitigate%20%250bimpacts%20of%20hydropower%20use%20%250bon%20aquatic%20environment.pdf	Taken into account. in the sentence "improvement are to be found mostly during the planning of a hydropower plant to minimise environmental and social impacts"	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy
51077	34	3	34	15	To be consistent with the developement, in section 6.4.2.4, on "major nuclear accidents'', mention should be made in this paragraph of the risks of catastrophic accidents due to dam failures (the cumulative the death toll of historic catastrophic dam failures is indeed several orders of magnitude higher than the one of nuclear accidents) References: The World's Most Catastrophic Dam Failures: The August 1975 Collapse of the Banqiao and Shimantan Dams. Chapter 3 of: Qing, D., Thibodeau, J.G., Topping, A.R., Dai, Q., Yi, M., & Williams, M.R. (1998). The River Dragon Has Come!: Three Gorges Dam and the Fate of China's Yangtze River and Its People: Three Gorges Dam and the Fate of China's Yangtze River and Its People (1st ed.). Routledge. https://doi.org/10.4324/9781315502779 Dam Failure and Flood Event Case History Compilation, RCEM – Reclamation Consequence Estimating Methodology, interim, U.S. Department of the Interior/Bureau of Reclamation, June 2015, https://www.usbr.gov/ssle/damsafety/documents/RCEM-Methodology2015.pdf	Taken into account.	Eric PROUST	European Nuclear Society (ENS)	France
61213	34	3	34	15	adding the assessment on the content of the impact on biodiversity	Rejected due to lack of space. Environmental impact is considered in the sentense ""improvement are to be found mostly during the planning of a hydropower plant to minimise environmental and social impacts"	Jianguo WU	chinese research academy of environmental sciences	China
77365	34	3	34	3	add "as for all energy and infrastructure project" after the "(Moran et al. 2018)", before punctuation	Rejected. Such statement do not bring a new or complementary information nor improve the quality of the text.	Atle Harby	SINTEF Energy Research	Norway
20961	34	4	34	7	Introducing innovative projets to cope with this issues would be of great interest. I.e.: (Innovation is the key to Europe's future dams, Lempérière, Fry, Vigny. 2019) e.g.: "Fish cannon" experimented for salmon migrations in British Columbia (https://www.seattletimes.com/seattle-news/more-than-a-viral-sensation-the-salmon-cannon-could-bring-the-species-back-to-the-upper-columbia-after-90-years/)	Rejected. Due to lack of space no specific environmental solutions or innovation are described.	Government of France	Ministère de la Transition écologique et solidaire	France
29897	34	4	34	5	Please consider replacing this sentence with "Hydropower dams and abstractions may lead to lack of ecological continum, by barriers for fauna migration, sediments and flow, causing large modification to aquatic and riparioan habitats, if not sufficiently mitigated by measures by e.g. sediment pass, fish migration aid together with environmental flow" (CIS guidance no 37 - https://ec.europa.eu/environment/water/water-framework/facts_figures/guidance_docs_en.htm). We believe that this would expand the focus appropriately.	Accepted.	Government of Norway	Norwegian Environment Agency	Norway

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
45885	34	4	34	5	It should be expressed more clearly, that it is not just an obstruction of fish migrations, but that this has severe negative effects on the stocks of certain migratory species. We suggest the following sentence: "Hydropower dams and channels may obstruct fish migration with severe negative consequences for certain fish species and cause large modification to aquatic habitat." Furthermore, hydropower turbines also can cause enormous mortalities during downstream passage, further impacting on the stocks. This should also be mentioned explicitly. (Reid, A. J., Carlson, A. K., Creed, I. F., Eliason, E. J., Gell, P. A., Johnson, P. T. J., Kidd, K. A., MacCormack, T. J., Olden, J. D., Ormerod, S. J., Smol, J. P., Taylor, W. W., Tockner, K., Vermaire, J. C., Dudgeon, D. & Cooke, S. J. (2019): Emerging threats and persistent conservation challenges for freshwater biodiversity. Biol. Rev. Camb. Phil. Soc. 94, 849–873. doi: 10.1111/brv.12480)	Taken into considerantion. See comment 29897.	Government of Germany	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety International Climate Policy	Germany
29899	34	5	34	8	Hydropeaking issues; consider to add; "For regulated rivers downstream hydropower tailrace, the river habitat may be severely impacted by hydropeaking, if not ecosystem based management measures are adapted to the species and river characteristics (Hayes et al, 2019 - https://www.mdpi.com/2071-1050/11/6/1547)"	Taken into consideration. Hydropeaking is considered as "changes in natural river flow"	Government of Norway	Norwegian Environment Agency	Norway
79607	34	5			after fish migration, add ",material flows". The following sentence "below the hydropwer dam" most of the item could be after "The dam reservoir altersnatural river flow,…" . The considerable alterations of vegetation refers to the phase of flooding of the reservoir, with CH4 production, etc?	Taken into consideration. See comment 29897	Marc Daras	CentraleSupelecAlumni	France
79611	34	7			after temperature. You should add " The construction of a dam further rises question of sharing of water use between power and agriculture and fisheries." You only mention at l36 cross border questions which rise in many countries even without climate change!	Taken into consideration. The word economical is included to the sentense.	Marc Daras	CentraleSupelecAlumni	France
77359	34	8	34	8	Insert sentence "However, there is a large potential to mitigate negative impacts and develop sustainable hydropower projects following updated methods, guidelines and standards." see https://iha-project.webflow.io/publications/hydropower-sustainability-guidelines. IFC - World Bank Group. 2018. Environmental Flows for Hydropower Projects. Good practice handbook. Guidance for the Private Sector in Emerging Markets. Silva, AT, Lucas, MC, Castro-Santos, T, et al. 2017. The future of fish passage science, engineering, and practice. Fish & Fish. 2018; 19: 340– 362. https://doi.org/10.1111/faf.12258. The World Bank. 2016. World Bank Environmental and Social Framework. World Bank,Washington, DC.	Rejected due to lack of space. We state that these risks need to be carefully managed, and such implying that they can be managed. We just don't have the space to focus on more on such best practicies.	Atle Harby	SINTEF Energy Research	Norway
55667	34	11	34	13	This is the second mention of virtual energy storage for hydropower, but it is unclear exactly how this process works. Does it require dams located along the same river system or not?	Taken into account. An explanation of the concept of virtual energy storage is included in the sentence.	Government of United States of America	U.S. Department of State	United States of America
18231	34	13	34	15	(Section 6.4.2.3) "When large areas of land are flooded by dam construction, greenhouse gas emissions are significant and often more than those from natural lakes". It would perhaps be useful to explain this statement - e.g., how and why are GHG emissions significant, what does 'significant' mean, and what is the level of evidence / confidence?	Accepted. The sentense has been modified to comply with the comment.	Government of United Kingdom (of Great Britain and Northern Ireland)	Department for Business, Energy & Industrial Strategy	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
29901	34	13	34	15	Few empirical studies underpin this statement, and a more site-dependent statements is recommended; "When large areas of land are flooded by dam construction, greenhouse gas emissions may be significant especially in flat tropical areas, and often more than those from natural lakes. However, the few reported measurements of net emissions have shown considerable variation (Prairie et al, 2018 - https://link.springer.com/article/10.1007/s10021-017-0198-9).	Accepted. The sentense has been modified to comply with the comment.	Government of Norway	Norwegian Environment Agency	Norway
77357	34	13	34	15	There is a large pool of publications dealing with greenhouse gas emissions from hydropower and hydropower reservoirs (and other types of reservoirs). A lot of information is to be found in the "2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventorie", Chapter 7.3 Flooded land. A lot of publications do not consider net emissions, nor do they take into account a holistic view. Please enlarge the sources of references and include: Prairie, Y., Alm, J., Beaulieu, J., Barros, N., Battin, T., Cole, J., del Giorgio, P., DelSontro, T., Guérin, F., Harby, A., Harrison, J., Mercier-Blais, S., Serça, D., Sobek, S. & Vachon, D. (2017a) Greenhouse Gas Emissions from Freshwater Reservoirs: What Does the Atmosphere See? Ecosystems.	Accepted. The sentense has been modified to comply with the comment.	Atle Harby	SINTEF Energy Research	Norway
63163	34	15			Mini- and pico- hydrokinetic turbines do not raise the same ecosystem and GHG emissions concerns as large hydropower plants associated with dams. Turbines also can be placed in storm water or drinking water system pipes, averting ecosystem impacts. (Sklarew D. and J. Sklarew. 2018. Integrated water-energy policy for sustainable development. Foresight and STI Governance 12(4): 10-19. doi: 10.17323/2500-2597.2018.4.10.19; Sklarew, Jennifer, and Dann Sklarew. 2017. “Empowering Resilience in Energy and Water Systems: Addressing Barriers to Implementation of Urban Hydroelectric Micro-turbines.” In The CIP Report, July 2017. Center for Infrastructure Protection & Homeland Security, George Mason University.)	Noted.	Jennifer Sklarew	George Mason University	United States of America
69509	34	15			There could be a short development about the potential for repowering existing hydropower plants, increasing their output significantly with new, more efficient turbine technologies, reducing environmental impacts with oil-free turbines, fish-friendly turbines and aerating turbines that increase the dissolved oxygen content of waters flowing down the dams. Furthermore, repowering can be an occasion to increase the electrical capacity so as to use existing reservoirs in a more "peaky" mode to increase the flexibility of hydropower to accompany and shoulder the development of variable renewables such as solar and wind (see e.g. IEA, 2012, IEA Technology Roadmap: Hydropower)	Noted. This aspect is added to the first paragarph in response to another comment we discuss the need to modernise the aging hydropower fleet to increase generation capacity	Cédric PHILIBERT	Institut Français des Relations Internationales	France
9513	34	16	34	29	This section on hydro power and public support repeats the approach of previous sections in conflating general public attitudes towards a technology with local community responses, which are two different things.	Noted.	Patrick Devine-Wright	University of Exeter	United Kingdom (of Great Britain and Northern Ireland)
9515	34	16	34	29	There is no mention of the deconstruction of old hydro projects here, yet there is evidence that removing hydro projects from landscapes can also cause problems with social acceptance - see Keilty et al 2016: http://dx.doi.org/10.1016/j.geo	Noted. We refer to dam removed in earlier text, but we certainly don't have space to focus on the preciption and social acceptance of this issue	Patrick Devine-Wright	University of Exeter	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
9517	34	16	34	29	Sayan (2019 - https://doi.org/10.1016/j.erss.2019.101234) uses the concept of environmental justice to understand social acceptance of hydro power in Turkey, due to the stigmatisation of place involved in large scale hydro projects. This insight could be added to the text here.	Rejected due to lack of space.	Patrick Devine-Wright	University of Exeter	United Kingdom (of Great Britain and Northern Ireland)
29903	34	16	34	37	Please also refer to EUs taxonomy of sustainable fincanse and the EU CIS guidelines.	Rejected due to lack of space.	Government of Norway	Norwegian Environment Agency	Norway
43573	34	16	34	29	What about the public perception of disaster threats due to dam rupture or overflooding?	See response to comment 9515	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy
64235	34	16	34	16	Support for nuclear power does exist around the world as a well-established technology to mitigate the worst effects of climate change, along with other low-carbon energy solutions (e.g., renewable energy technologies) and with energy efficiency measures. Of course, the safety and security of nuclear power plants must be continuously enhanced throughout its life cycle. This statement is shared by the IPCC (see many of its reports since 2014) and was clearly stated by the head of the IPCC in his lecture at the International Conference on Climate Change and the Role of Nuclear Power (Vienna, August 29, 2019). https://www.iaea.org/newscenter/news/ipcc-head-to-speak-at-international-conference-on-climate-change-and-the-role-of-nuclear-power "Climate Change and the Role of Nuclear Power", International Atomic Energy Agency's (IAEA), Vienna, 7 to 11 Oct 2019 "Clearly, 1.5 degrees C pathways are consistent with everything from negligible nuclear power to a tenfold increase in nuclear power over the next three decades. The opportunity exists. The challenge is how much of the opportunity will you be able to catch up? Time is critical, so the share of the opportunity you capture will depend on the speed at which nuclear technology can be deployed." * EN - https://ideesrecuessurlenergie.wordpress.com/2019/10/19/hoesung-leespeech-ipcc-president-from-the-iaea-conference/	WRONG section -- should be nuclear	Georges VAN GOETHEM	Royal Academy of Overseas Sciences (ARSOM - KAOW)	Belgium
84481	34	16	34	17	There appears to be opportunities to increase relevant context based on the feasibility assessment in the chapter.	Rejected due to lack of space.	Siir KILKIS	The Scientific and Technological Research Council of Turkey	Turkey

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
76609	34	21	34	24	This paragraph does not take into account the fact that some components which become more brittle with aging, like pressure vessels, cannot be replaced nor refurbished. Technical literature assesses that the thermal aging of steels under irradiation of nuclear vessels accelerates rapidly beyond 40 years lifetime for all 900 MWe reactors (which make up more than a half of the French nuclear fleet). Lifetime extension thus increases the risk of a sudden vessel fracture under pressurized thermal shock, which would lead to loss of reactor control and major Fukushima-like accident. On this subject, see the meta-research proposed by Larochelambert, Th. De, Steels aging under irradiation - Risk of nuclear reactor vessels breakage, 2019, International Nuclear Information System, INIS-FR--20-0817 See also G.R. Odette et al., On the history and status of reactor pressure vessel steel ductile to brittle transition temperature shift prediction models, Journal of Nuclear Materials 526 (2019) 151863.	WRONG section -- should be nuclear	Charlotte MIJEON	Réseau "Sortir du nucléaire" (organiszation affiliated to the French Climate Action Network)	France
79609	34	23			You give exemple of Chile, but similar concerns have risen in Brasil, and could not be voiced in China, for instance.	Noted. Chile is given as an example, we and don't have the space to provide a fuller list of such areas.	Marc Daras	CentraleSupelecAlumni	France
76611	34	26	34	34	These assumptions regarding small modular reactors (SMRs) seems overly optimistic and are at odds with the state of the art. SMR actually seem to be plagued by the same issues that are affecting large-scale reactor projects: delays, cost overrun and the increased availability of low-carbon alternative at rapidly decreasing costs. Until now, their cost per MWh is significantly higher than large-scale plant. This tends to make a broad diffusion in the 2020s rather unlikely. According to the World Nuclear Industry Status Report (Schneider et al., 2020), only two SMR have been completed so far, namely floating reactors in Russia whose construction lasted 4 time more as initially projected and whose costs are 6 time higher, significantly more expensive than Generation III design. One reactor has been in construction since 2014 in Argentina and is said to be half-completed ; another one is in construction in China since 2012 and has experienced 4 years delay. China National Nuclear Corporation acknowledged that the construction cost per kW was twice higher than of a large NPP. As for the NuScale design, its licensing application has been postponed for years and the National Regulatory Commission identified significant safety problems. According to NuScale, its LCOE would be 65 US$/MWh, which makes it broadly uncompetitive with other low-carbon sources.	WRONG section -- should be nuclear	Charlotte MIJEON	Réseau "Sortir du nucléaire" (organiszation affiliated to the French Climate Action Network)	France
17811	34	30	34	33	Highly recommend to add additional info on GHG emissions based on life cycle assessment of hydropower plants not only about duration of hydropower plants construction (as already in text). Please add after the sentence - "As a result of social and environmental constraints only a small fraction .... in developed countries" - the following info: e.g. According to International Reference Center for Life Cycle of Products, Services and Systems (CIRAIG), the greenhouse gas (GHG) emission rate of hydropower calculated based on a life cycle assessment is lower than for other renewables.	Rejected. This paragarph is about the construction time of hydro plants and not GHGs.	Sergey Chestnoy	UC RUSAL	Russian Federation

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
19909	34	30	34	33	Highly recommend to add additional info on GHG emissions based on life cycle assessment of hydropower plants not only about duration of hydropower plants construction (as already in text). Please add after the sentence - "As a result of social and environmental constraints only a small fraction .... in developed countries" - the following info: e.g. According to International Reference Center for Life Cycle of Products, Services and Systems (CIRAIG), the greenhouse gas (GHG) emission rate of hydropower calculated based on a life cycle assessment is lower than for other renewables.	Rejected. This paragarph is about the construction time of hydro plants and not GHGs.	Yulia Dolinina	UC RUSAL	Russian Federation
61763	34	30	34	37	Regarding hydroreservoirs, it would be prudent to mention that the filling time of the reservoir may be more than a decade due to basin flow constraints. See the case of the Grand Ethiopian Reneissance Dam (Zhang et al, 2016, http://doi.org/10.1080/02508060.2016.1178467).	Accepted	Rauli Partanen	Think Atom	Finland
65805	34	30	34	37	In discussing the construction time of hydroreservoirs, it would be reasonable to mention also that the filling time of the reservoir may be significant due to basin flow constraints, even more than a decade. See, for example, the case of the Grand Ethiopian Reneissance Dam (Zhang et al, 2016, http://doi.org/10.1080/02508060.2016.1178467)	Accepted.	Eero Hirvijoki	Aalto University	Finland
55669	34	32	34	32	This should say, "… only a small fraction of the potentially economic hydropower projects can be developed …"	Accepted	Government of United States of America	U.S. Department of State	United States of America
43151	34	37	34	38	The chapter (in different places) uses the terminology 'green hydrogen', 'blue hydrogen'… without explaining its meaning. This reference catergorises the different types of hydrogen labels. Source: Velazquez Abad, A. and P. E. Dodds (2020). "Green Hydrogen Characterisation Initiatives: Definitions, Standards, Guarantees Of Origin, and Challenges." Energy Policy 138: 111300.	Noted but the commemt seems out of place.	Abad Velazquez	Transport Research Laboratory	United Kingdom (of Great Britain and Northern Ireland)
1555	34	38	37	14	This section does not appear to present a well-balanced viewpoint with a more balanced presentation required to be consistent with other sections. The ratings given are highly questionable and would not reflect the opinion of the informed community at large. No mention is made of weapons proliferation, which needs to be addressed since energy growth is expected mainly in regions of the world that are not politically stable, with civilian nuclear clearly the clandestine path to developing weapons in many countries. Specific comments follow.	Noted. Proliferation is discussed at the end of the section to te extent of allowed space.	Martin Green	UNSW Sydney	Australia
4781	34	38	37	14	Section 6.4.2.4. fails to perform a sustainability assessment of nuclear power; the section paints a much too favourable picture of nuclear technology, bordering on advocacy. The authors of section 6.4.2.4 skip the literature which presents facts relevant for policy-making on nuclear power and/or which provides independent analysis of nuclear power as a low-carbon electricity supplier. The practice of systematically skipping relevant literature contradicts the IPCC 'Principles Governing IPCC Work, section 4.3.3', requesting the assessment of all peer-reviewed literature, and "clearly identify disparate views for which there is significant scientific or technical support, together with the relevant arguments." (www.ipcc.ch). Defying a crucial principle of IPCC assessment work discredits the results and IPCC reputation. The omissions and biases in section 6.4.2.4 are many, as following comments show.	Rejected. This section is expected to give a broad sense of main charracteristics (technological, economical, environmental, institutional, etc) that determine the ability of nuclear's and other technologies' to contribute to mitigation, and these are presented to the extent of allowed space. The expert reviewer does not provide other spporting peer-reviewed literature.	Aviel Verbruggen	University of Antwerp	Belgium

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
8981	34	38	37	14	This Sub-section concerns mainly with the technological and economic aspects of nuclear energy, including its overall LCA-based impact and the socio-political problems of its acceptance and the disposal of radioactive waste. Security issues are raised only with respect to standard operation and management, while several past accidents have been attributed to scarce human skills and technical knowledge due to bad personnel selection procedures. This aspect does not depend on engineering aspects. It is also interesting to observe that Fukushima engineers addressed as the "cause of the incident" the unpredictability of such a strong earthquake with such a high subsequent tsunami wave. A simple calculation performed just by taking some public data, for example those from the U.S. Geological Survey database on the power-law frequency of earthquakes and the likelihhod of a big earthquake in the eastern coastal zone of Japan, along with the expected lifetime of a nuclear plant, should have indicated the incident as much probable, sooner or later. The discussion on possible parallel proliferation of nuclear weapons is limited to few lines. No reference is made to one of the most critical aspects of nuclear plants, that is, the potential effects of a terrorist attack on the plant. Since the possible global political instability due to the global warming effects, and the fact that most of the nuclear plants worldwide cannot be adequately protected and are located near or within high population density areas, this aspect should be also taken into account and reported properly.	Noted. See comment 4781	Francesco Gonella	Ca' Foscari University of Venice, Italy	Italy
19185	34	38	36	30	Data on safety expendetures are needed, because safety constitutes a susbtantial part in the costs. Also, safety procedures, licensing, vary from one developer to another. For example, China offers shorter period of approval hence capital costs are lower, but the lower cost can happen on expenses of nuclear safety. NuScale in the US is currently under approval as the first SMR reactor, needs to be mentioned. see NICE Future website and reports http://www.cleanenergyministerial.org/initiative-clean-energy-ministerial/nuclear-innovation-clean-energy-future-nice-future	Noted. Within allowed space, safety concerns are covered by improved standards and guidelines which are applied in design and approval process.	Andrei Belyi	University of Eastern Finland	Finland
28333	34	38	37	14	Although it is true that nuclear power is globally declining, it is equally true that many countries are either planning or building new nuclear power plants. Therefore I find puzzling that no numerical evidence is offered in this section on the carbon intensity of nuclear energy, particularly when this is offered in other parts of this chapter (e.g. solar energy) to emphasise the great variability that exists. Since most of the benefits of nuclear energy come from the high carbon energy sources it aims to replace, offering these numbers (and showing the great variability they have) is paramount when countries are already decarbonising their grids and therefore the merit for nuclear power is less and less clear. This would challenge the high confidence with which this section opens (L39) about nuclear power remaining an option to deliver low-carbon energy at scale. There are several robust studies and reviews in premier journals that offer numerical results for different ranges of assumptions within the nuclear energy spectrum and I really think a numerical overview should be offered in the chapter. Studies I am aware of are:https://doi.org/10.1016/j.enconman.2008.01.033; https://doi.org/10.3390/en9110863; https://doi.org/10.1111/j.1530-9290.2012.00472.x; https://doi.org/10.1016/j.enpol. 2008.04.017; https://doi.org/10.1016/j.apenergy.2021.116743;	Noted. Nuclear is a low carbon source of producing energy, there is a wde consensus on that. Regarding the ranges for carbon intensities: the main reason of not prviding them in the text is the lack of space. Nuclear is given half the allowed space as compared to e.g. solar energy.	Pomponi Francesco	Edinburgh Napier University	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
48117	34	38	34	44	Please don't state that "nuclear remains a viable option. Nuclear output worldwide in 2019 was less than in 2006. Please also clearly mention that another major problem with nuclear is the long time between planning and operation -10 to 19 years for all plants around the world. Thus new nuclear costs 5 times new wind or solar (Lazard, 2020) and takes on the order of 8-18 years longer between planning and operation so is not a "viable optionl." In fact, given it takes an average of 15 years for one reactor, and we need 80% of the problem solved by 2030, nuclear is all but useless for helping to solve the climate problem. Please also mention upfront its other issues, namely weapons proliferation, meltdown risk and uranium mining risks: Chapter 3 of Jacobson, M.Z., 100% Clean, Renewable Energy and Storage for Everything, Cambridge University Press, New York, 427 pp., 2020	Noted. For some countries it is a viable option, for others not.	Mark Jacobson	Stanford University	United States of America
51079	34	38	37	14	Subsection 6.4.2.4 Nuclear Energy only presents it as a low-carbon power (electricity) generation technology. Mention should be made of the application of nuclear energy (just like fossil fuel energy) in a cogeneration mode to produce both together low-carbon electricity and large amounts of low-carbon heat that can be used to decarbonise district heating, desalination and/or process heat. The use of nuclear energy for cogeneration provides many economic, environmental and efficiency-related benefits. Cogeneration using existing nuclear reactors is a mature technology: the global nuclear desalination accumulated experience is 250 reactor years, whereas that of nuclear district heating is over 500 reactor years [1]. China has started deploying nuclear cogenerated district heating to decarbonise this sector [2]. Cogeneration of low-carbon hydrogen by alkaline water electrolysis (electrical coupling) could increase the economic efficiency of load following by nuclear power plants in an electricity mix with a large share of variable renewable power. Cogeneration of electricity and low-carbon hydrogen by high-temperature steam electrolysis and even more by termochemical processes are more attractive because of their capability to produce hydrogen with higher efficiency. However, the coupling of SMRs and+ hydrogen facilities working at high temperature (about 800 °C) still requires substantial R&D to reach commercialization [3]. Finally, advanced reactors under development (liquid-metal fast reactors, modular high-temperature gas cooled reactors) would be well suited to cogenerate high-temperature process heat for hard-to-decarbonise industry sectors [4]. [1] Opportunities for Cogeneration with Nuclear Energy, IAEA Nuclear Energy Series No. NP-T-4.1 (2017) [2] China daily, New heating project to cut fossil fuel, Updated: 2021-01-08, http://www.chinadaily.com.cn/a/202101/08/WS5ff7c851a31024ad0baa15b9.html [3] Giorgio Locatelli, Sara Boarin, Andrea Fiordaliso & Marco E. Ricotti, Load following of Small Modular Reactors (SMR) by cogeneration of hydrogen: A techno-economic	Taken into account.Thank you for the references, if the space allows, a sentence will be added on that.	Eric PROUST	European Nuclear Society (ENS)	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
61765	34	38	37	14	The section 6.4.2.4 "Nuclear energy" should explicit mention also the applications in hydrogen production. The paper (Kayfeci et at. 2019, https://doi.org/10.1016/B978-0-12-814853-2.00003-5) lists hydrogen from nuclear at a price comparable to that from biomass and by far cheaper than from solar or wind. The most recent report (LucidCatalyst, 2021, https://www.lucidcatalyst.com/hydrogen-report) lists hydrogen from existing nuclear PWR technology at less than $2/kg and from GENIV technology at $1/kg or less. This can be cost-competitive with hydrogen from steam reformation of natural gas. As a source of high-quality steam, nuclear also enables the usage of high-temperature steam electrolysis, which increases the electrolysis efficiency by a third (to 90+%) compared to low-temperature electrolysis.	Accepted. Text was revised to include applications in hydrogen production.	Rauli Partanen	Think Atom	Finland
64237	34	38	34	47	At the international level, there is a consensus that the maximum level of passive safety can be obtained through geological disposal. It is believed that the continuous increase in our knowledge through RD&D contributes to increasing confidence in the arguments that demonstrate the safety and feasibility of geological disposal. It is worth mentioning in this context the European Technology Platform for the Implementation of Geological Disposal of Radioactive Waste (IGD-TP), created in 2010, which aims to foster, promote and accelerate the implementation of geological disposal. The mission of the IGD-TP is to be a tool to support the strengthening of confidence (public and regulatory) in the safety and implementation of deep geological disposal solutions. https://igdtp.eu/activity/secigd-secretariat-of-the-implementing-geological-disposal-technology-platform/	Noted.	Georges VAN GOETHEM	Royal Academy of Overseas Sciences (ARSOM - KAOW)	Belgium
65807	34	38	37	14	The section 6.4.2.4 "Nuclear energy" should explicitly mention the applications in hydrogen production. The paper (Kayfeci et at. 2019, https://doi.org/10.1016/B978-0-12-814853-2.00003-5) lists hydrogen from nuclear at a price comparable to that from biomass and by far cheaper than from solar or wind. The most recent report (LucidCatalyst, 2021, https://www.lucidcatalyst.com/hydrogen-report) lists hydrogen from existing nuclear PWR technology at less than $2/kg and from GENIV technology at $1/kg or less. This is cost-competitive with hydrogen from steam reformation of natural gas. Revise accordingly.	Accepted. Text was revised to include applications in hydrogen production.	Eero Hirvijoki	Aalto University	Finland
76633	34	38	37	33	This part should also adress the issue of nuclear decommissioning and document its cost.	Noted. Decommissioning is accounted in the price of electricity during the operation of nuclear power plant. More extensive discussion on this topic is beyond the scope of this doc.	Charlotte MIJEON	Réseau "Sortir du nucléaire" (organiszation affiliated to the French Climate Action Network)	France
76635	34	38	37	33	In order to provide a complete overview of the issue, this part should include some developments on the costs of a nuclear accident.	Rejected. This is beyond the scope of main characteristics that detemine abiility of technologies to contribute to mitigation.	Charlotte MIJEON	Réseau "Sortir du nucléaire" (organiszation affiliated to the French Climate Action Network)	France
79613	34	38			There is a question of global organisation of the chapter as before. It seems that the logic should be to carry on on renewable energy, especially biomass which is an important element, then Nuclear and finally CCS.	Not applicable. The comment should be refered to section 6.4 in general.	Marc Daras	CentraleSupelecAlumni	France
84321	34	38	37	14	include a consideration on the link between the nuclear implementation in countries where the energy-intensity of the industry increases (CN, IN…)	Taken into account. Although interesting, this discussion can not be considered due to lack of space.	Vincent MAZAURIC	Schneider Electric	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
86307	34	38	37	14	The costs of electricity $/MWh etc as stated in this section - it is not clearly understood it includes all costs. For example, costs can provide a better representation when the life cycle cost is considere - for examling including the cost of nuclear waste storage which has major cost and environmental implications.	Rejected. The reference for cost is provided. Life cycle cost is not discussed for any technology sections.	RABIZ FODA	Hydro One Networks Inc.	Canada
12197	34	39	34	44	With regards to public perception, the text should also reflect the regaining of support for nuclear in countries such as Japan (which announced the restart of its nuclear fleet) and also Germany after the Energiewende impact on carbon emissions. Please see the Comparative Analysis of Public Attitudes toward Nuclear Power Energy across 27 European Countries by Applying the Multilevel Model, 2018, by Jaesun Wang and Seoyong Kim to understand that public support for nucler in Europe has either increased or stayed the same with traditional coal dependent countries such as Poland joining the nuclear family.	Taken into account. The restart of nuclear fleet in Japan does not translate automatically to the regain of public support for nuclear. Similar applies to Germany, Poland.	Lavinia Rizea	SN Nuclearelectrica SA	Romania
14693	34	39	34	44	To be comprehensive, this summary should also include Life Time Extensions, which are cost-effective options (OECD NEA IEA 2020).	Noted. It includes to the extent possible.	Cécile Seguineaud	Indépendant consultant	France
18827	34	39	34	41	There should be added "in some countries" after the words "reactor designs". There are new nuclear build projects in e.g. Russia, China or South Korea being build on time and on budget. Naturally there could be lower price when there is a significant number of one type reactor produced, but there are also countries where reactors are build in terms of planned budget.	Taken into account. The addition will not change the message of the sentence, thus will not be considered.	Tomáš Martanovič	Ministry of Industry and Trade	Czech Republic
19637	34	39	34	41	The statement should be modified into: Nuclear power remains a viable option to deliver low-carbon energy at scale (high confidence). Doing so will require improvements in managing construction projects of proven reactor designs (ADD-in some countries) (DELETE - that hold the promise of lower costs and broader use) (medium confidence). There is a number of nuclear construction projects in countries like South Korea, China, Russia, Belarus with no major delays or cost overruns (according the same chapter construction of NPP newbuilds at page 35, line 40). So the there is no "promise" of lower costs, the low costs are a reality but this is country-dependent.	Taken into account. The suggestion would modify the message of the sentence, thus will not be considered.	Government of Slovakia	State Advisor, Climate Change Policy Department Ministry of the Environment	Slovakia
37129	34	39	34	44	The present share of renewables is substantially low compared to almost 11 % of world's electricity	Noted	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37131	34	39	34	44	supplied by nuclear energy. Increasing the capacity of nuclear is probably the most effective solution for	Noted	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37133	34	39	34	44	the Carbon free energy. This is particularly true for developing nation like India with high GDP growth rate and rising population. India with the highest population density in the world; renewables alone can not meet the large energy demand in the country. Nuclear has to play important role in the clean energy mix. The energy density of nuclear is the largest; Advanced nuclear reactors based on passive technologies are quite safe and have great potential to replace coal based plants. Nuclear can provide base load with the highest capacity factor.	Noted	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
55671	34	39	34	39	Caveat "technically where politically/socially acceptable".	Noted	Government of United States of America	U.S. Department of State	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
55673	34	39	34	41	China, Russia, and South Korea have done quite well managing nuclear construction projects. (https://www.sciencedirect.com/science/article/pii/S0301421516300106) Further, the question of ""proven reactor designs"" vs. more advanced designs is perhaps a question of deployment time scale. Is there any other technology for which the IPCC is calling for the deployment of ""proven designs"" only, without encouraging innovation? Suggest changing sentence to: ""Doing so will require managing construction projects of reactor designs that hold the promise of lower costs and broader use (medium confidence).""	Accepted. Text revised.	Government of United States of America	U.S. Department of State	United States of America
61769	34	39	34	41	“Doing so will require improvements in managing construction projects of proven reactor designs that hold the promise of lower costs and broader use (medium confidence.)” Most construction project problems referred here are present in western nations that had a long hiatus in construction and started with FOAK-designs. The vast majority of global nuclear projects are progressing relatively well and on budget, and this should be mentioned. Rephrase into more informative: “Apart from the FOAK-projects in the EU and the US which started with unfinished designs and no recent experience of such projects, nuclear projects have been progressing relatively well and on budget due to continuous, serial construction of finished design by experienced management teams, multiple reactors at one site, and learning from experience.” See ETI nuclear Cost Drivers Project, 2020, https://es.catapult.org.uk/reports/nuclear-cost-drivers/.	Taken into account. Most of the issues are true for all countries, with some exceptions for China, but general message is correct.	Rauli Partanen	Think Atom	Finland
71587	34	39	34	44	safety problems should also be mentioned in this first paragraph. Also - safer reactors are more expensive which makes nuclear decreasingly competitive especially in countries with high safety standards.	Taken into account. High-upfornt investment needs includes all the safety requirements needed.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
76401	34	39	34	44	This section portrays nuclear energy as beset by cost overruns but fails to recognise that this is largely limited to a small number of plants built by the US and French industries as they restart their nuclear energy programmes. There are some 50 nuclear power plants being constructed world wide and the issues that have occurred at Vogtle in the USA or Flammanville in France have not impacted upon the Korean, Chinese or Russian industries as the roll out projects in the UAE, Pakistan, India, China, Russia or Turkey. Cost of capital has never been lower and this needs to be addressed in this narrative as it makes the construction of nuclear energy currently more competitive. The issue surrounding the disposal of used nuclear fuel need to be addressed. Paths forward are quire clear. We have three options that have been known for decades 1.Open fuel cycle with direct deep geological disposal of spent nuclear fuel resulting in 4.08 m3/TWh of High Level Waste (HLW) 2.Mono Recycle as practiced in France which recycles the used fuel once and results in a large decrease of HLW to 0.7m3/TWh 3.Multi recycle which is dependant on the ultimate diversion of used fuel to fast spectrum reactors and results in 0.2m3/TWh of HLW. Multi recycle will in effect increase the energy ouput per unit mass of uranium by around 30 fold and in effect render the earth's uranium resources as infinite – it will be the ultimate renewable energy source. It will make the recovery of the 4.5 billion tones of uranium in sea water entirely commercially viable. The disposal of nuclear waste has been studies for decades and is entirely secure in deep geological repositories where wate flows of only a few metres per million years mean that the material is entirely secure and remote from the biosphere. The Fukushima Daiichi incident is a prime example of appalling media engagement. No individual has been proven to have died as a result of radiation and there is only a small chance that any will in the future. Despite this, nuclear energy has been	Taken into account. These differences between regions are provided later on in the text.	Robert Parker	Nuclear for Climate Australia	Australia
78611	34	39	34	44	the statement that nuclear energy remains a 'viable option to deliver low-carbon energy' is NOT anymore true for new built plants, as such nuclear plants are nowadays the HIGHEST electricity cost option, as confirmed by various sources. Thus such a general, and factually wrong statement requires correction. Sources for real nuclear cost are: WEO 2020 of the IEA see Tables B.2a/b, the Lazard reports (https://www.lazard.com/media/451419/lazards-levelized-cost-of-energy-version-140.pdf), and scientific literature, such as Ram et al. (https://www.sciencedirect.com/science/article/pii/S0959652618321486).	Noted. Some of these sources are already used to the extent needed.	Christian Breyer	LUT University	Finland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
82639	34	39	34	44	The current passage is somewhat unclear. How can nuclear be viable but also require improvements? In fact only some nuclear plants have experienced significant cost over runs, while others are delivered close to their budgets. I think this should be clarified in the text. Again, a good description of nuclear economics can be found in the OECD 'Projected Costs of Generating Electricity' report (https://www.oecd-nea.org/jcms/pl_28612/projected-costs-of-generating-electricity) It concludes The statement that public acceptance and political support for nuclear has 'only' decreased since the Fukushima Daiichi accident is also not really backed by evidence. In fact most public national acceptance polls showed a short term dip in support following the accident before recovering - see https://www.ipsos.com/ipsos-mori/en-uk/nuclear-energy-update-poll. It is to the best of my knowledge true that support for nuclear energy is lower than most other energy sources across most countries, although there has not been a global poll for years. In addition Several newcomer countries have started to build their first nuclear power plants in the years since the Fukushima Daiichi accident. This includes Belarus, UAE, Turkey and Bangladesh Both support for nuclear and the economic viability varies significantly be country	Noted. Anything viable can still be improved and deployed wider. This reference was used in text.	Jonathan Cobb	World Nuclear Association	United Kingdom (of Great Britain and Northern Ireland)
18831	34	41	34	44	See comment no. 5 (add "in some countries" after the word "political support).	Accepted. Text revised to varying political support, not low.	Tomáš Martanovič	Ministry of Industry and Trade	Czech Republic
19639	34	41	34	44	The statement should be modified: At the same time, nuclear power in some countries continues to be beset by cost overruns, high up-front investment needs, (DELETE -challenges with ultimate disposal of radioactive waste), and low public acceptance and political support (ADD-in some countries), (DELETE-which has only decreased since the Fukushima Daiichi accident) (high confidence). As mentioned above, not all the nuclear new build projects are hit by cost overruns (according the same chapter construction of NPP newbuilds at page 35, line 40). Radioactive waste disposal is a problem of public perception and not a technical or economical issue, however Finland and Sweden have successfuly managed to overcome it as well as USA in case of high-level waste disposed of in Waste Isolation Pilot Plant in New Mexico since 1999. Public acceptance for nuclear power today in many countries is higher than right after Fukushima accident in 2011, e.g. in Sweden, Finland, Poland and even in Austria.	Taken into account. The suggestion for the first pharagraph would modify its message, thus will not be considered. Differences among countries/regions for new builds are discussed later in the text. The reviewer did not provide literature sources for the statements about increased public acceptance in some countries after Fukushima accident.	Government of Slovakia	State Advisor, Climate Change Policy Department Ministry of the Environment	Slovakia
37679	34	41	34	44	Cost and time overruns can be overcome by adopting standardised design and planning. Reactors at Tarapur, India (540 MW PHWR) were constructed within budget and schedule. India plans to go in for construction of several reactors (700 MW, PHWR) in fleet mode to address the issue of cost and time overrun. The issue of waste can be addressed by adopting a closed fuel cycle and going in for partitioning of minor actinides as demonstrated by India. Some other countries are following similar path. Political support exist in many countries such as India. For details, please see Grover, R. B., and M. R. Srinivasan, 2020, “Vikram Sarabhai: His vision for the development of Atomic Energy in India”, Current Science, 118(8): 1191-1195.	Noted. Thank you.	Ravi B Grover	Homi Bhabha National Institute	India

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
47045	34	41	34	44	Another problem with nuclear energy, the impacts of mining ores of uranium, among other sources, should also be included in this statement to objectively present the dangers of this energy resource.	Rejected. The reviewer does not provide supporting literature.	John Leo Algo	Living Laudato Si' Philippines	Philippines
55675	34	41	34	42	In the west, nuclear power has been beset by cost overruns, but this is not true to nearly the same extent in China, South Korea, etc. This study is more careful in its language: ""The stubbornly high capital cost of new nuclear plants, along with lengthy construction delays, is a major factor in the dim outlook for new nuclear power plant construction in the United States and Western Europe."" http://energy.mit.edu/research/future-nuclear-energy-carbon-constrained-world/ Note also a study out of MIT concluded that power plants based on existing designs costs more, not less, than plants based on new designs. https://www.cell.com/joule/fulltext/S2542-4351(20)30458-X	Taken into account. In some countries cost overruns are because of designs, in some countries lenghty construction delays because of managing the projects. Regional differences are discussed later in the text.	Government of United States of America	U.S. Department of State	United States of America
61771	34	41	34	44	“At the same time, nuclear power continues to be beset by cost overruns, high up-front investment needs, challenges with ultimate disposal of radioactive waste, and low public acceptance and political support, which has only decreased since the Fukushima Daiichi accident (high confidence).”This whole sentence is highly misleading and even incorrect. Cost overruns are present in a limited set of projects in the EU and US, with known and fixable reasons for those cost overruns. The vast majority of projects around the world are relatively well on budget – rephrase to include this as well. See ETI nuclear Cost Drivers Project, 2020, https://es.catapult.org.uk/reports/nuclear-cost-drivers/. Part 1/3	Taken into account. Thank you for the reference. But the reference discusses cost reduction opportunities rather than compares cost-overruns, which are encountered to different extent in most of the prjects, in particular FOAK.	Rauli Partanen	Think Atom	Finland
61773	34	41	34	44	Part 2/3. Challenges with disposal of radioactive are political, not technical, economic nor related to safety or public health. There are multiple safe and economic methods to handle the waste. The first final repository has been licenced, permitted and is now under construction in Finland, with Sweden following closely behind. Rephrase waste part to reflect this.	Noted. This is already in the text.	Rauli Partanen	Think Atom	Finland
61775	34	41	34	44	Regarding public acceptance and political support, the stated is simply incorrect. The public acceptance depends greatly on country, and many countries have seen the public support for nuclear improving. While a handful of nations have decided to phase out nuclear (Germany, Belgium, Switzerland), there is roughly ten times more newcomers and potential newcomers interested in adapting nuclear energy. Replace the part with for example this quote from UNECE 2021: “Interest in nuclear energy has grown in response to rising energy demand, the emerging climate crisis, and the global sustainable development agenda… Roughly 28 newcomer countries are considering, planning or starting nuclear power programmes.” (https://unece.org/sustainable-energy/publications/nuclear-entry-pathways).	Rejected. A number on potential newcomers does not automatically translate to improved public perception and aceptance.	Rauli Partanen	Think Atom	Finland
65809	34	41	34	44	"At the same time, nuclear power continues to be beset by cost overruns, high up-front investment needs, challenges with ultimate disposal of radioactive waste, and low public acceptance and political support, which has only decreased since the Fukushima Daiichi accident (high confidence)." This is an incorrect statement and must be revised. For costs, see Figure 1 in https://es.catapult.org.uk/reports/nuclear-cost-drivers/ which shows only plants in Europe and US to suffer from cost overruns while plants built elsewhere are economic and have benefitted from significant learning (e.g., the 4 Barrakah units of UAE, in Fig. 21). For waste, the first final repository has been licenced, permitted and is now under construction in Finland https://inis.iaea.org/collection/NCLCollectionStore/_Public/44/091/44091445.pdf , with Sweden following. Revise accordingly.	Taken into account. Figure 1 in the mentioned publication shows capital costs of different projects, not not cost-overruns, let's say not initial announced budget vs ex-post construction cost.	Eero Hirvijoki	Aalto University	Finland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
74193	34	41	34	44	The claim that there is low public acceptance and political support for nuclear power (high confidence) is factually incorrect. While there are some countries for which nuclear power support is low, Germany and Japan, that is not the case elsewhere. Additionally, there are significant investments in nuclear by a variety of countries including the U.S., Canada, England, Russia, and China.	Rejected. The reviewer does not provide supporting literature.	Jeffrey Merrifield	Pillsbury Law Firm	United States of America
77227	34	42	34	43	Apart from the low public and political support, all other arguments are subject of strong debates: - As discussed further in the text, cost overruns refer to first-of-a-kind projects: not only this would apply also to the first PV, wind, coal, whatever plant, but is true only in some western countries, while in others new builds projects run on time and to budget. It is thus not generally valid. - High up-front investment needs make no sense per se: once compared to the energy potential of the plant, they turn comparable or even lower to any other source (as discussed further as well). - Ultimate disposal of radioactive waste is not a technical problem, as proven by the licensing and next operation of geologic disposal facilities; rather, at least, a matter of public acceptance. In summary, all these should not be reported.	Rejected.. Nuclear power costs vary substantially across countries. The text provides exmaples of higher and lower costs depending on regions.Regarding, investmet needs, individual nuclear projects can hardly be done by private capital. Regarding waste, text is not refering to waste as being a technical issue.	Giacomo Grasso	ENEA	Italy
8915	34	43	34	44	"which has only decreased since the 44 Fukushima Daiichi accident (high confidence)" This is not true and highly depending on the country under review. For instance, in France, the confidence in nuclear power is now increasing (see for instance: https://www.irsn.fr/FR/IRSN/Publications/barometre/Documents/IRSN_Barometre_2020-analyse.pdf)	Taken into account. According to the question n3 in the mentioned publication: in 2019 French people believe more (33) that nuclear can cause a serious accident then they did in 2010 (32).	Jean-Guy DEVEZEAUX DE LAVERGNE	Université Paris-Dauphine & Société Française d'Energie Nucléaire	France
77229	34	43	34	44	The statement "which has only decreased since the Fukushima Daiichi accident" is hard to defend: - in Germany and Italy - two of the countries where the public opinion suffered the most from the Fukushima Daiichi accident - in the last few years the public opinion has been raising in favor of nuclear. - Japan is continuously restarting plants and looking to future projects. - The US and Canada launched renewed nuclear programs after Fukushima. - China extended further its already aggressive nuclear programme. - A number of countries worldwide are starting new programs - many more than those where nuclear programs are being reduced or halted.	Noted. The reviewer does not substantiate his arguments with the literature.	Giacomo Grasso	ENEA	Italy
79615	34	43	34	44	suppress "which has onlydecreased since the Fukushima Daichi accident." beacuse it is not essential, and very confusing because you should state first that following Fukushima the acceptance was at is lowest. Nota tehrefore it should rise later on!	Accepted. Text revised.	Marc Daras	CentraleSupelecAlumni	France
79707	34	43			see above for substantive. Change sentence to " and public acceptance and political support, which has decreased in some countries since the Fukushima Daiichi accident, but has remained stable and even increased (UK) in other countries. See sources above for reports	Accepted. Text revised, but no country reference will be made. The reviewer did not provide literarture sources.	valerie faudon	SFEN	France
18819	34	44	34	44	We suggest adding to the text: „The mix of variable renewable energy sources with stable nuclear sources is effective way to decarbonisation. Renewable and nuclear resources complement each other. The mix will ensure the stability of electricity production and price stability.“ (According to studies published by Nuclear Energy Agency of IEA)	Rejected. Not possible to add something like that out of nowhere - it's system dependent	Tomáš Martanovič	Ministry of Industry and Trade	Czech Republic
9167	34	45	34	45	Please reformulate "unlikely that resource scarcity will provide a constraint" into a positive manner, for example "the present estimated Uranium ressource are sufficient for a nuclear deployment targeting the climate mitigation"	Acepted. Text revised.	Marin Constantin	RATEN ICN	Romania

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
20963	34	45	34	46	This sentence is strange. Suggestion : There is sufficient Uranium ressource to nuclear deployment at meaningful scales for climate mitigation.	Acepted. Text revised.	Government of France	Ministère de la Transition écologique et solidaire	France
51081	34	45	34	45	"unlikely that resource scarcity will provide a constraint": strange wording. Consider rephrasing, for exemple "Uranium ressource is likely sufficient for nuclear deployment at meaningful scales for climate mitigation"	Acepted. Text revised.	Eric PROUST	European Nuclear Society (ENS)	France
61767	34	45	35	5	The very large uranium resources in the oceans should be mentioned, especially as the technology for extracting uranium from seawater has advanced rapidly in the last few years. The resource is also replenished constantly, so it is effectively renewable and the cost of seawater extraction sets an effective ceiling to the long-term price of uranium fuel. See Pacific Northwest National Laboratory, 2018, https://www.pnnl.gov/news/release.aspx?id=4514 and the related literature (Kuo et al., 2020, https://doi.org/10.1039/c9dt04562g.	Taken into account. The resource is not a constraint - that is the main message.	Rauli Partanen	Think Atom	Finland
65811	34	45	35	5	In discussing the availability of uranium reserves, it would be worth to mention the estimated reserves in seawater, especially since the technology for extracting uranium from seawater has advanced in leaps. This would have tremendeous potential in reducing the ecological impact of uranium mining. See the news article (Pacific Northwest National Laboratory, 2018, https://www.pnnl.gov/news/release.aspx?id=4514) and the related literature (Kuo et al., 2020 https://doi.org/10.1039/c9dt04562g).	Taken into account. The resource is not a constraint - that is the main message.	Eero Hirvijoki	Aalto University	Finland
78479	34	45	35	5	This paragraph has an incomplete argumentation and partly unclear references. I assume the writers wanted to avoid the difficult topic of how much (conventional) uranium there is available for mining, and finally the writers came to agree on this text. So let's leave the numbers like agreed upon: 130 years of supply at the 2016 level of uranium requirements (62,825 tU). This paragraph, however, needs a few additional sentences to put this number into perspective of what is stated in the agreed text as "nuclear deployment at meaningful scales for climate mitigation". I suggest to add before "In an unlikely case of uranium resource scarcity..." the following sentences: "Currently, about 10 % of the world's electricity is generated in nuclear power plants. This implies that if nuclear power were expanded threefold, the conventional uranium sources known today would be exhausted by about 2050. This places stricter limits on its deployment than the material availability for wind energy and photovoltaics and the associated electricity storage."	Noted. The references are clear. The message is that the resource is not a constraint because its estimates over time are increasing (without much effort) and there are alternatives in an unlikely case of uranium scarcity.	Pietro Altermatt	Trinasolar, Changzhou, China	Germany
979	34	47			tU? Check this	Noted. tonnes of uranium	Alok Dhaundiyal	Szent Istvan University	Hungary
1011	34			37	Discuss about radio active disposal(LLW) and the effect on the ocean (kindly include biomagnification). HLW dispoal'https://www.osti.gov/etdeweb/servlets/purl/20177738'	Noted. Disposal is discussed, no additional text could be acomodated due to lack of space.	Alok Dhaundiyal	Szent Istvan University	Hungary

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
64823	34		37		Conventional nuclear power plants (NPPs) is the most significant low carbon technology for electricity and heat generation. Existing units are the most safe, reliable and weather-independent power stations with minimum environmental impact and death toll compared to other technologies including Wind and Solar Power Plants (WaSPP), even considerig major accidents. It shall be emphasized, that Three Mile Island and Fukushima have no serious radiological consequences. New NPPs are being built mostly in China, India, Russia, Turkey, Pakistan, Abu Dhabi, Finland, Slovakia, France and the USA. New units are planned or considered in France, Ukraine, Egypt, Czech Republic, Hungary, Poland, Romania and Slovenia. Nuclear option can lead to net-zero carbon energy sector as can be seen in Ontario, Canada. Modern NPPs have flexible capacity and are suitable to complement volatile and unpredictable WaSPP, as proven by successfull long-term operation of French and German NPPs. Technologies for spent nuclear fuel management are available, spent fuel reprocessing plants are working in France and Japan, deep depositories are under development or construction in Sweden. Low-level radioactive waste management is the same as for medical and industrial (institutional) radioactive waste. Financial instruments covering spent fuel and radioactive waste management expenses are in place. Small Modular nuclear Reactors (SMR) is the relatively new way how to overcome problems with high CAPEX of conventional NPPs. Technical development is going on in the USA, China, Russian Federation, United Kingdom, Argentina and France. Complex country programmes for SMR deployment are in place in Canada and Finland. SMR promises significant CAPEX reduction due to plant capacity scaling by gradual adding of new modules, faster investment return, serial factory-based production of individual modules and modular design. SMR are designed for flexible electricity production, municipal heating and process heat production, hydrogen production, fresh water production by desalination, electrical grid control services etc. Due to more robust design they can be deployed in distributed pattern near to major consumers (cities and industrial centres). Small and micro reactors are especially	Noted	Radek Svoboda	Czech Nuclear Society	Czech Republic
4177	35	1	35	2	When estimating the conventional supplies of uranium at 130 years, the distinction should be included as to the percentage breakdown of the two isotopes (U-235 & U-238) that contribute to that estimated 130-year reserve.	Noted. The reference used does not make a breakdown when delivering the message. More detailed analysis can not be acomodated due to allowed space.	Neil M. Mulchan	Adventure Physics, LLC	United States of America
61977	35	1	35	1	Typo: change "conventional resources are estimated to over 130 years" to "conventional resources are estimated to correspond over 130 years"	Noted. No change is needed	Esa Vakkilainen	LUT University, Lappeenranta	Finland
15525	35	2	35	5	It is necessary to include plutonium to the sentence «... uranium's alternative – use of plutonium and thorium - might regain interest...» https://www. world-nuclear. org/information-library/nuclear-fuel-cycle/fuel-recycling/plutonium. Aspx	Noted. Plutonium is problematic because of proliferation	Vladimir Kucinov	National Research Nuclear University "MEPHI" (Moslow Enginiring Physical Institute)	Russian Federation

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
77231	35	2			Before mention to thorium, uranium extraction from seawater should be worth mentioning. E.g.: "Unconventional resources could also be exploited, such as extraction of uranium from seawater. This technology, being developed in America, Japan and China and quickly progressing, has shown the viability of uranium extraction at costs that could be comparable in a near future to those of conventional resources. Extraction of uranium from seawater (estimated in 4 billion Mt of uranium) would be sufficient to fuel a thousand 1,000 MW nuclear power plants for a 100,000 years. Besides this, the uranium extracted is replenished continuously, extending the available resources almost indefinitely." Source: "Uranium in Seawater". Special issue of Industrial & Engineering Chemistry Research 55(15), (2016)	Accepted. The resource is not a constraint - that is the main message. Text will be added only if space allows.	Giacomo Grasso	ENEA	Italy
79617	35	2			Before "In an unlikely…" a sentence should be added to give a view of nuclear in the energy production because the reserve are for a limited production. Insert " However, these reserves are aclculated on the base of the present contribution of nuclear to the electricity production, 10%, or of TFE of 2% appr.	Rejected. That's assumed already. Resources are not an issue, in case there would be expansion of nuclear, there would be more efforts on extraction. Even without much efforts, resource base has been increasing over years.	Marc Daras	CentraleSupelecAlumni	France
981	35	6			remove article 'established tech.'	Noted	Alok Dhaundiyal	Szent Istvan University	Hungary
61777	35	6	35	7	“Gen III nuclear power is already an established technology, but there are several other technology options available in the 2030-2050 planning horizon (medium confidence).” This is incorrect, as some of these other technology options are already being built. Rephrase: “Gen III nuclear power is already an established technology, and there are several other technology options either in the design and licencing phase with planned FOAK projects starting in the 2020s, or already under construction, such as the HTR-PM in China (see e.g. https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/small-nuclear-power-reactors.aspx).”	Noted. Very small difference - curent wording covers this.	Rauli Partanen	Think Atom	Finland
79619	35	6	35	7	The wrapping sentence which announce several option for 2030-2050, should be followed in the text of an evaluation of the different options of GEN IV, for instance after l 34. Otherwise, the promise of future is only in SMRs which are only subject to market conditions. GEN IV givse different perspective in nuclear fuel and waste.	Noted. Gen IV is not discussed among the options for deployment in 2030-50.	Marc Daras	CentraleSupelecAlumni	France
15527	35	7	35	7	To replace “medium confidence” by “high confidence”, because commercial Generation IV technologies will be available before 2050. Nuclear Technology Review 2020, Printed by the IAEA in Austria September 2020 IAEA/NTR/2020	Rejected. The text does not refer to Gen IV reactors. IAEA assumes that this technology will be available in 2050.	Vladimir Kucinov	National Research Nuclear University "MEPHI" (Moslow Enginiring Physical Institute)	Russian Federation
4783	35	11	35	12	Most design, development, demonstration, and building of such ‘non-water coolant’ reactors took place in the 1960-1990 period. What lessons are derived from these experiments?	Noted	Aviel Verbruggen	University of Antwerp	Belgium
9169	35	11	35	12	Please reformulate "Generation-IV is the classification used to describe a set of advanced reactor designs that use non-water coolants" by using a most appropriate definition of Gen-IV (for example Locatelli, Giorgio; Mancini, Mauro; Todeschini, Nicola (2013-10-01). "Generation IV nuclear reactors: Current status and future prospects". Energy Policy. 61: 1503–1520)	Taken into account. Gen IV is not discussed among the options for deployment in 2030-50.	Marin Constantin	RATEN ICN	Romania
31461	35	11	35	12	The Supercritical water (SCWR) Generation IV concept use water as coolant.	Noted	Carolina Ahnert	Universidad Politécnica de Madrid	Spain

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
31463	35	11	35	12	Generation-IV have as some of the Generation-III passive safety systems, and some of them are fuel breeders	Taken into account. Text wil be removed on classification of reactors.	Carolina Ahnert	Universidad Politécnica de Madrid	Spain
51083	35	11	35	12	"Generation-IV is the classification used to describe a set of advanced reactor designs that use non-water coolants": The main characteristics of Generation IV reactor designs is not that they are using non-water coolant (by the way, some are using supercritical water), their main characteristic is that they are designed to offer significant advantages over GenII/III+. I therefore suggest to add "some of which exhibit a considerable increase (>x60) increase in the efficiency of uranium resource use [1] and greatly reduced impact in terms of radioactive waste" [2] References: [1] Limits to growth: Can nuclear power supply the world's needs? Derek Abbott First Published November 4, 2016 Research Article , Bulletin of the Atomic Scientists 68(5) 23–32 https://doi.org/10.1177/0096340212459124	Noted	Eric PROUST	European Nuclear Society (ENS)	France
64239	35	11	35	12	A lot more emphasis should be put on Generation IV in the subject IPCC report. Generation IV reactors (Gen IV) are a set of nuclear reactor designs currently being researched for commercial applications by the Generation IV International Forum (GIF). They are motivated by a variety of goals including improved safety, sustainability, efficiency, and cost. The most developed Gen IV reactor design, the sodium fast reactor, has received the greatest share of funding over the years with a number of demonstration facilities operated. The principal Gen IV aspect of the design relates to the development of a sustainable closed fuel cycle for the reactor. The molten-salt reactor, a less developed technology, is considered as potentially having the greatest inherent safety of the six models. The very-high-temperature reactor designs operate at much higher temperatures. This allows for high temperature electrolysis or for sulfur–iodine cycle for the efficient production of hydrogen and the synthesis of carbon-neutral fuels. According to the GIF timeline, Gen IV reactors might enter commercial operation around 2045. Advantages and disadvantages. Relative to current nuclear power plant technology (Generations II and III), the claimed benefits for 4th generation reactors include: • Nuclear waste that remains radioactive for a few centuries instead of millennia[34] • 100–300 times more energy yield from the same amount of nuclear fuel[35] • Broader range of fuels, and even unencapsulated raw fuels (non-pebble MSR, LFTR). • In some reactors, the ability to consume existing nuclear waste in the production of electricity, that is, a closed nuclear fuel cycle. This strengthens the argument to deem nuclear power as renewable energy. • Improved operating safety features, such as (depending on design) avoidance of	Noted. Many thanks for this background. "Gen IV reactors might enter commercial operation around 2045" or they might not. This might be more clear for the next IPCC reports.	Georges VAN GOETHEM	Royal Academy of Overseas Sciences (ARSOM - KAOW)	Belgium
84313	35	11	35	12	Non-water coolant is not the main characteristic of the 4th generation. The closure of the fuel management with waste combustion seems more relevant [https://www.gen-4.org/gif/].	Noted	Vincent MAZAURIC	Schneider Electric	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
20965	35	12	35	12	About "[...] development today": Some of these designs allow a considerable (>x60) increase of the uranium resource Limits to growth: Can nuclear power supply the world's needs? Derek Abbott First Published November 4, 2016 Research Article , Bulletin of the Atomic Scientists 68(5) 23–32 https://doi.org/10.1177/0096340212459124	Noted	Government of France	Ministère de la Transition écologique et solidaire	France
4785	35	13	35	13	When did it enter? Which new phase? Detailed data are delivered by the yearly World Nuclear Industry Status Report (WNISR), for example WNISR (2020, p.22): countries are currently building nuclear power plants, one more than in mid-2019, as Iran restarted construction of Bushehr-2 site, originally launched in 1976. As of 1 July 2020, 52 reactors were under construction—of which 15 in China with 14 GW of capacity, less than half of the 5-Year target of 30 GW by the end of 2020. Total capacity under construction in the world amounts to 53.5 GW. The current average time since work started at the 52 units under construction is 7.3 years, on the rise for the past two years from an average of 6.2 years as of mid-2017. Many units are still years away from completion.	Noted. Entered a new phase of evolutionary design constructions, after AR5 more extensively.	Aviel Verbruggen	University of Antwerp	Belgium
4787	35	19	35	25	Long-term operation (LTO) of the current fleet is an important factor, but evidence about the success of LTO is at least mixed, for example, US utilities closing nuclear plants earlier than the license allows. The references in this section are IAEA, NEA and IEA, seemingly describing LTO as only a technical issue. According to WNISR (2020, p. 21), many reactors are being closed long before their licenses expire; the mean age at closure of the 17 units taken off the grids between 2015 and 2019 was 42.4 years.	Rejected. The text refers to LTO (Most U.S. reactors already have seen their licenses extended to 60 years from 40 years), and not to the analysis of the factors of closure of the mentioned reactors. Some of these factors are mentioned at the end of the section.	Aviel Verbruggen	University of Antwerp	Belgium
983	35	20			two-thirds	Accepted. Text revised	Alok Dhaundiyal	Szent Istvan University	Hungary
20967	35	21	35	22	We suggest to replace the word "typically" by "often considered" in the sentence: "The design lifetime of previous generation reactors is often considered 40 years." because the report in reference use the term "consider", and actually several nuclear power plants have different frameworks (some reactors have a 30-year licence, other have unlimited licence, and the concept of design lifetime for a whole plant is not universal, so it is difficult to state that 40 years is "typical".)	Noted. Suggested change does not change the message of the sentence.	Government of France	Ministère de la Transition écologique et solidaire	France
61779	35	21	35	22	Replace "design lifetime" with "initial design lifetime". As has been discovered, the design lifetime of reactors can be extended to at least 80 years, which is currently the longest operation licence granted.	Taken into account. Both are used interchangeably.	Rauli Partanen	Think Atom	Finland
20969	35	22	35	24	This part leaves the parts that cannot be replaced such as the vessel, suggestion, add before "key components" the word "replaceable "	Accepted. Text revised	Government of France	Ministère de la Transition écologique et solidaire	France
72887	35	22	35	24	This sentence on refurbishment of existing generation III reactors should be completed with the issue of vessels. Suggestion, add before "key components" the word "replaceable " and then a short sentence "This does not apply to vessels or parts that cannot be replaced. "	Accepted. Text revised	Antoine BONDUELLE	EE-Consultant	France
51085	35	23	35	23	"if key components … are replaced": Please add "replaceable" ("if key replacable components …are replaced") Otherwise the reader may wonder whetherit is possible to replace key components.onder.,	Accepted. Text revised	Eric PROUST	European Nuclear Society (ENS)	France
5351	35	24	35	24	Delete "Cooling Towers". Life extension have been granted for may units in the US without building new cooling towers.	Note. It is stated as an example of something that can be replaced.	Michel SIMON	Retraité/ Pdt d'association	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
61781	35	24	35	25	“The lifetime extension considered in most of the countries is 10 to 20 years (OECD IEA NEA 2020).” This is misleading as it gives the impression that only a single lifetime extension can be done, which is not the case. Rephrase: “A single lifetime extension considered in most of the countries is 10 to 20 years (OECD IEA NEA 2020), but multiple extension can be done in succession, and some reactors already have been licenced to operate for 80 years (UNECE 2021, https://unece.org/sustainable-energy/publications/nuclear-entry-pathways).	Accepted. Text revised to "first extension"	Rauli Partanen	Think Atom	Finland
18815	35	25	35	25	We suggest adding to the text: "Some countries are already preparing legislation to allow for 80 years or more. LTO is a major challenge for IPA operators. It requires to ensure systematic management of NPP aging, which would determine the maximum operation time of the NPP, both in terms of safety and production economy."	Accepted. Text revised to "first extension", meaning that there could be subsequent extensions.	Tomáš Martanovič	Ministry of Industry and Trade	Czech Republic
31465	35	25	35	25	Some nuclear power plants in US got extension approval to 80 years	Noted	Carolina Ahnert	Universidad Politécnica de Madrid	Spain
51087	35	25	35	25	"... 10 to 20 years (OECD IEA NEA 2020)": add "although extension of a few nuclear units up to 80 years has already been appouved in the US". Reference: https://www.nrc.gov/reading-rm/doc-collections/news/2019/19-062.pdf	Accepted. Text revised to "first extension", meaning that there could be subsequent extensions.	Eric PROUST	European Nuclear Society (ENS)	France
4789	35	26	35	28	More precise status description, based on a diversity of references is needed. The WNISR as most complete yearly reference report (moreover Open Access) refers to one SMR with a generic license (NuScale in the USA) and three under construction (two High Temperature Reactors at Shidao Bay since 2012 in China; CAREM in Argentina)	Accepted. The issue is space to expand on details and examples.	Aviel Verbruggen	University of Antwerp	Belgium
28507	35	26	35	34	It is surprising not to see any reference to literature pointing to challenging conclusions on the capacity of SMRs to present a lower cost of generating each unit of electrical energy than LRs should definitely be added here. See the section entitled "Overall SMR economic competitiveness" in this article: https://www.sciencedirect.com/science/article/pii/S1364032119307270. In particular, see the part on "main areas of disagreement" for of critical views.	Taken into account. Thank you for the reference.	Pierpaolo Cazzola	International Transport Forum	France
63641	35	26	35	34	The authors may want to consult the OECD-NEA report on SMRs (https://www.oecd-nea.org/jcms/pl_14924/small-modular-reactors-nuclear-energy-market-potential-for-near-term-deployment) which discusses how SMRs are endeavouring to respond to safety concerns by incoroporating inherent and passive safety systems.	Taken into account. Will be included onlu if space allows.	Government of Canada	Environment and Climate Change Canada	Canada
74195	35	26	35	34	It should also be noted that the high temperatures of advanced non-light water nuclear reactors allows for the use in non-power systems such as desalination, chemical process technologies and the production of hydrogen and ammonia for transportation uses.	Accepted. Text was revised to include applications in hydrogen production.	Jeffrey Merrifield	Pillsbury Law Firm	United States of America
985	35	27			the conceptual	Accepted. Revised	Alok Dhaundiyal	Szent Istvan University	Hungary
17503	35	27	35	27	FOAK?, mentioned later in line 36	Accepted. Revised	Alaa Al Khourdajie	IPCC	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
4791	35	28	35	29	The statement "SMRs are expected to offer lower overall investment (units of less than 300MW)" is either trivial (less MW evidently offer less investment expenses), or misleading because not stated in $/kW or $/kWh. By now, all SMR projects (PBMR in South Africa was abandoned; Akademik Lomonosov in Russia took 12.7 years to build vs. 3.7 years planned; Shidao Bay in China and CAREM in Argentina already 9 and 7 years under construction) failed to demonstrate adavantage over GEN III performance. IPCC should cover the full story in a non-partisan way.	Taken into account. Text revised.	Aviel Verbruggen	University of Antwerp	Belgium
48543	35	28	35	28	Clarify by adding 'costs' after 'investment'.	Accepted. Revised	Kathleen Araujo	CAES Eenrgy Policy Institute/Boise State University	United States of America
55677	35	29	35	31	While this may be true, China, for example, has chosen to build large plants despite capability to build smaller ones, so this increased efficiency should be regarded as conjecture not fact. Suggest revising sentence to: "Modularity and off-site pre-production may allow greater efficiency in construction, shorter delivery times, and overall cost optimisation (IEA, 2019b)."	Accepted. Text revised.	Government of United States of America	U.S. Department of State	United States of America
987	35	31			an increased…	Accepted. Revised	Alok Dhaundiyal	Szent Istvan University	Hungary
4793	35	31	35	31	"increased load-following capability" is a technical aspect; however load-following has also financial impacts because it reduces the load factor of the plant. Plants with high investment costs (such as nuclear plants) are most sensitive to lowering of load factors. The higher the share of wind and PV power grows, the more the load factors of nuclear capacities will be challenged.	Noted	Aviel Verbruggen	University of Antwerp	Belgium
55679	35	31	35	32	Since most of these designs have never been built, nobody knows for sure what they offer. Suggest revising sentence to: "Most SMR designs aim to offer increased load-following capability that would make them suitable to operate in smaller systems and in systems with increasing shares of variable renewable sources."	Accepted. Text revised	Government of United States of America	U.S. Department of State	United States of America
989	35	34			the 2020s	Accepted. Text revised.	Alok Dhaundiyal	Szent Istvan University	Hungary
18823	35	34	35	34	We suggest adding to the text: "SMR has significant potential for heat production for urban heating and industrial purposes after coal combustion."	Accepted. Text was revised to include applications in hydrogen production.	Tomáš Martanovič	Ministry of Industry and Trade	Czech Republic
4795	35	35	35	36	“Nuclear has proven economically competitive in some countries and uncompetitive in others (high confidence).” The statement should be made more precise. What does ‘economically competitive’ mean here? Of the currently operational NPPs, not one has been constructed in the context of a fully liberalized electricity market. Furthermore, Wealer et al. (2019) conclude that investing in nuclear power plants in current liberalized markets in the EU and the United States is not profitable from a private investor perspective, i.e. expected net present values are highly negative, mainly driven by high construction costs, including capital and financing costs, and uncertain and low revenues. Markard, J., Bento, N., Kittner, N., Nuñez-Jimenez, A. (2020) equally ob-serve that an eroding actor base, shrinking opportunities in liberalized electricity markets, the breakup of existing networks, loss of legitimacy, increasing cost and time overruns, and abandoned projects are clear indications of a sector in decline. They conclude that, while there might be a future for nuclear in state-controlled power sectors such as in Russia or China, new nuclear power plants do not seem likely to become a core element in the struggle against climate change. This however proves the fact that nuclear power has to be shielded from competition in order to be implemented.	Accepted. Sentence was removed.	Aviel Verbruggen	University of Antwerp	Belgium

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
17349	35	35	35	36	"Nuclear power costs vary substantially across countries. Nuclear has proven economically competitive in some countries and uncompetitive in others." Second statement can be written for any source of electricity. The statement should rather read: ""Nuclear represents the cheapest large-scale source of dispatchable low-carbon electricity." Reference US EIA Annual Energy Outlook 2020.	Accepted. Sentence was removed.	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
18835	35	35	35	36	There should be added "in case of competition with subsidized electricity sources". Nuclear power is competitive in markets using technological neutrality and not promoting or subsidizing any energy source. It is impossible for any energy source to compete on market basis against subsidized energy sources.	Taken into account. This is covered later in the text.	Tomáš Martanovič	Ministry of Industry and Trade	Czech Republic
19641	35	35	35	36	The statement should be modified: Nuclear has proven economically competitive in some countries and uncompetitive in others, (ADD-where it must compete against subsidized energy sources on the electricity market, which does not reward one of the major element which is security of supply) (high confidence). Nuclear power is competitive in those markets which provide a level playing field for all energy sources and market participants. It is impossible for any energy source to compete on market basis against subsidized energy sources (and "subsidies" means not only out-of-market payments like feed-in tariffs but also any other economic and regulatory means which give a priviledged energy source an administrative advantage against other eneregy sources e.g. grid access priority).	Taken into account. This is covered later in the text.	Government of Slovakia	State Advisor, Climate Change Policy Department Ministry of the Environment	Slovakia
76613	35	35	35	40	Not just FOAK Gen II and Northern American and European nuclear newbuild projects are experiencing delays. According to the World Nuclear Industry Status Report (Schneider et al., 2020), as for 2020, at least 33 of the 52 unit under construction were behind schedule. Over the past decade, the average construction time (from start to grid connection) was 10 years. All but 1 out of 15 reactors connected to the grid in 2018-2019 have experienced delays, these delays reaching 4 years or more for 11 of them (See the graph provided by Schneider et al., 2020 : https://www.worldnuclearreport.org/IMG/pdf/wnisr2020-figure8-nuke-world-constructiontime2018-2019.pdf). This makes nuclear newbuild a rather unreliable option with regard to the quick implementation of mitigation solutions required by climate emergency, a point that could be worth being emphasized in this part.	Taken into account. This is covered in the text.	Charlotte MIJEON	Réseau "Sortir du nucléaire" (organiszation affiliated to the French Climate Action Network)	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
83641	35	35	35	35	The statement 'Nuclear has proven economically competitive in some countries and uncompetitive in others (high confidence).' is at odds with the some other passages in this paragraph and the best available reports on this subject. Some individual projects have experienced cost over-runs, but there is good reason to believe that costs will fall on subsequent projects in these countries as a result of learning and introducing best practise, see Unlocking Reductions in the Construction Costs of Nuclear (https://www.oecd-nea.org/jcms/pl_30653/unlocking-reductions-in-the-construction-costs-of-nuclear). While new nuclear projects may be more expensive than other low carbon technologies (notably wind and solar) on an LCOE basis, they may still contibute to lowering the overall costs of electricity on a systems basis - see OECD NEA report Full costs of Electricity Provision (https://www.oecd-nea.org/jcms/pl_14998/the-full-costs-of-electricity-provision) As stated in the paragraph the long term operation of nuclear plants is among the cheapest generating option available So more nuance is necessary in the statement. It would, according to the evidence presented surely be more accurate to say that nuclear power is 'economically compeititve in most/many countries' or that 'nuclear energy will help reduce decarbonization costs in most countries'.	Taken into account. This is covered in the text, including the reference.	Jonathan Cobb	World Nuclear Association	United Kingdom (of Great Britain and Northern Ireland)
5353	35	36	35	36	Give refrence stating that nuclear is uncomprtitive in some countries?	Accepted. Sentence was removed.	Michel SIMON	Retraité/ Pdt d'association	France
19643	35	36	35	39	The statement should be modified: First-of-a-kind (FOAK) GEN III/III+ projects under construction in Northern America and Europe were marked by delays and costs overruns (Berthelemy and Rangel 2015) – with Finland and France as the extreme cases - where construction times exceed 13-15 years and cost surpass 3-4 times the initial budgets, (ADD- but even in those cases the projected electricity generation costs remain affordable e.g. in Finland with Olkiluoto-3 at 40 EUR/MWh) (OECD IEA NEA 2020, S&P 2020). See: https://www.fitchratings.com/research/corporate-finance/fitch-revises-teollisuuden-voima-oyj-outlook-to-negative-affirms-at-bbb-20-04-2020)	Taken into account. "Remain affordable" depends on countries and it needs to be compared to alternatives.	Government of Slovakia	State Advisor, Climate Change Policy Department Ministry of the Environment	Slovakia
9171	35	38	35	38	Reformulate "with Finland and France as the extreme cases" by introducing projects instead of countries and a supporting reference for "extreme"	Accepted. Text revised.	Marin Constantin	RATEN ICN	Romania
20971	35	38	35	39	Does it make sense to put emphasis on the extreme rather than the average ?	Taken into account. It highlights regional differences.	Government of France	Ministère de la Transition écologique et solidaire	France
20973	35	38	35	38	We suggest to remove the mention "with Finland and France as the extreme cases", because 1) it discriminates the French technology EPR and 2) it is not an accurate statement since other technologies and FOAK projects have encountered similar difficulties (for example AP1000 projects in the USA).	Accepted. Text revised.	Government of France	Ministère de la Transition écologique et solidaire	France
31467	35	38	35	39	Should be included the average building time, not the maximum	Rejected. It specifically refers to FOAK projects in Europe and Northern America.	Carolina Ahnert	Universidad Politécnica de Madrid	Spain

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
51089	35	38	35	38	The mention "with Finland and France as the extreme cases" should be removed. Indeed, it is an inaccurate statement (other technologies and FOAK projects have encountered similar difficulties, for instance AP1000 projects in the USA) and this statement is discriminatory against French EPR technology	Accepted. Text revised.	Eric PROUST	European Nuclear Society (ENS)	France
51091	35	38	35	39	"where construction times exceed 13-15 years and cost surpass 3-4 times the initial budgets": emphasis should be made on the average/mean case rather than on extremes cases	Rejected. It specifically refers to FOAK projects in Europe and Northern America. Further in text, 6 years construction period is mentioned for other regions.	Eric PROUST	European Nuclear Society (ENS)	France
76615	35	38	35	39	Construction time for both EPR reactors in Finland and in France are now over 13-15 years, reaching 16 years. Concerning the French Flamanville 3 reactor, initial costs have actually been multiplied by 5 if one takes into account the evaluation of the Cour des Comptes (French national audit office) issued in July 2020 of €2015 19.1 billion euros.	Noted	Charlotte MIJEON	Réseau "Sortir du nucléaire" (organiszation affiliated to the French Climate Action Network)	France
55681	35	39	35	39	The Vogtle plant also has cost over-runs of that scale .	Noted	Government of United States of America	U.S. Department of State	United States of America
72919	35	39	35	39	The figure "3-5 times" quoted from NEA-OECD 2020 is misleading in the case of the French EPR construction in Flamanville. The official "Cour des Comptes" in France comes to a total of 19,1 Bn€ for an initial estimate of 3,3 Bn€, or close to six times(!). Maybe write "well over" ?	Taken into account.	Antoine BONDUELLE	EE-Consultant	France
4797	35	40	35	40	The statement "recent projects in China and Korea have been executed within 6 years" is factually wrong: Only one reactor, Fuquing-5 in China, in 8 Gen III reactors connected to the grid 2018-2020 in China and Korea has been built in this timeframe. The other 6 started up in China between 8.3 and 9.2 years of construction. The only one connected in Korea (Shin-Kori-4) took 10 years to build.	Taken into account. Text was revised and reference added.	Aviel Verbruggen	University of Antwerp	Belgium
20975	35	40	35	40	There is no reference for the figure "6 years" related to constructions in China and Korea. The 2020 NEA report (that is quoted) gives different figures for Gen III/III+ (9 years for China, 8-10 years for Korea). So it seems to be a mistake : unless another reference document justify the "6 years", it should be replaced by "8-9 years".	Taken into account. Text was revised and reference added.	Government of France	Ministère de la Transition écologique et solidaire	France
991	35	44			the lesson	Accepted. Text revised	Alok Dhaundiyal	Szent Istvan University	Hungary
1557	35	44	35	46	The costs estimates here are aspirational rather than reflecting "new build" reality. Costs are reasonably transparent for "new build" Hinkley C, able to benefit from experience with the Olkiluoto and Flamanville plant. Contract price is presently USD147/MWh (see above) and increasing with inflation until the plant starts, then subsequently. IEA put nuclear LCOE in 2020 at USD65-150/MWh, not expecting any substantial decrease to 2040 where USD60-110/MWh is anticipated. Lazard gives 2020 LCOE at a more realistic USD129-198/MWh. More independent input like this is needed in this section.	Rejected. The cost ranges are referenced. The reference relies on the direct contributions on generation cost data from the governments of both OECD and non-OECD countries. It is also reviewed by Expert Group consisting of experts from government, academia and industry	Martin Green	UNSW Sydney	Australia
4799	35	44	35	46	The chapter's text here is factually wrong: OLKILUOTO 3 was the EPR FOAK, but FLAMANVILLE 3 current cost estimates are similar if not higher, and even adjusted cost estimates for HINKLEY POINT C remain in the same range. There is no public information available on Taishan. However, their construction also took more than twice as long as planned. The latest cost of electricity estimate for FLAMANVILLE 3 by the French Court of Accounts is USD133-145/MWh (€110-120/MWh). See Cours des Comptes, La filière EPR, July 2020, p.14	Rejected. The cost ranges are referenced. The reference relies on the direct contributions on generation cost data from the governments of both OECD and non-OECD countries. It is also reviewed by Expert Group consisting of experts from government, academia and industry	Aviel Verbruggen	University of Antwerp	Belgium

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
48545	35	44	35	44	FAOK should be FOAK	Acepted. Text revised.	Kathleen Araujo	CAES Eenrgy Policy Institute/Boise State University	United States of America
71589	35	44	35	46	why are expected subsidies in the UK substantially above the cost range mentioned? Costs could be even higher than reported here.	Rejected. The cost ranges are referenced. The reference relies on the direct contributions on generation cost data from the governments of both OECD and non-OECD countries. It is also reviewed by Expert Group consisting of experts from government, academia and industry	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
76617	35	44	35	46	No deadline is mentioned in this sentence	Noted	Charlotte MIJEON	Réseau "Sortir du nucléaire" (organiszation affiliated to the French Climate Action Network)	France
76619	35	44	35	46	The range may actually be higher, since the electricity produced by Flamanville 3 and Hinkley Point C (which are not first-of-a-kind projects), according to the French Cour des comptes, is expected to range €2015 110-120/MWh. Overall, figures provided by OECD NEA would require challenging by non-industry-related sources since its projections have regularly proven overly optimistic (See also Schneider et al. and particularly this graph taken from the World Nuclear Industry Status Report 2019 : Projections vs reality https://www.worldnuclearreport.org/IMG/pdf/wnisr2019-figure2-nuke-world-oldprojections.pdf)	Rejected. The cost ranges are referenced. The reference relies on the direct contributions on generation cost data from the governments of both OECD and non-OECD countries. It is also reviewed by Expert Group consisting of experts from government, academia and industry	Charlotte MIJEON	Réseau "Sortir du nucléaire" (organiszation affiliated to the French Climate Action Network)	France
78613	35	44	35	46	nuclear LCOE shall be based on a broader set of references which show a higher range of costs than listed in the rather old (2015) reference used. Additional references with provided cost are the following ones: WEO 2020 of the IEA see Tables B.2a/b, the Lazard reports (https://www.lazard.com/media/451419/lazards-levelized-cost-of-energy-version-140.pdf), and scientific literature, such as Ram et al. (https://www.sciencedirect.com/science/article/pii/S0959652618321486) - all published later and providing a broader set of insights.	Rejected. The reference is 2020, not 2015.	Christian Breyer	LUT University	Finland
82641	35	44	35	44	FAOK - > FOAK	Accepted. Text revised	Jonathan Cobb	World Nuclear Association	United Kingdom (of Great Britain and Northern Ireland)
5355	35	45	35	45	add in this sentence that cost estimates depends heavily on the interest rates used for LCOE.	Rejected. It says it depends on various factors.	Michel SIMON	Retraité/ Pdt d'association	France
84315	35	45	35	46	provide the investment cost (in capacity).	Taken into account. No need - it gives idea on generation cost, which is enough.	Vincent MAZAURIC	Schneider Electric	France
993	35	47			cost-competitive	Taken into account. Used in both ways.	Alok Dhaundiyal	Szent Istvan University	Hungary

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
4801	35	47	35	48	The text of the chapter is factually wrong: Many units are closed because they cannot compete in the grid (see WNISR2020, Table 9). In FR, the Court of Accounts has estimated the costs at USD121 billion (€100 billion) for backfitting of EDF's fleet for the time period 2014–2030. Considering the massive additional upgrading requests for lifetime extensionsl l'Autorité de Sûreté Nucléaire just released, this number is to be revised significantly upwards. The US power grid has seen PV Purchasing Power Agreements at prices lower than USD20/MWh, the EU grid holds the record low PV cost at USD13.5/MWh (€11.14/MWh) see https://www.reuters.com/article/portugal-energy-solar-idUSL8N2FR3GE. PV and wind in Spain come in with PPAs around USD30/MWh (€25/MWh), which is less than the average current nuclear O&M costs in France.	Noted. The text does not discuss closures. Indirectly, at the end of the section some factors mentioned could be related to the closures.	Aviel Verbruggen	University of Antwerp	Belgium
76621	35	47	36	2	Figures provided by the OECD NEA require challenging by non-industry-related sources. The affirmation « the overnight cost of lifetime extensions is estimated in the range of USD 390-630/kWe for Europe and North America » is anyway at odds with the findings of the IEA itself (IEA (2019), Nuclear Power in a Clean Energy System, IEA, Paris), which estimates that « The estimated cost of extending the operational life of 1 GW of nuclear capacity for at least 10 years ranges from $500 million to just over $1 billion depending on the condition of the site ». Even this latter estimation seems quite optimistic. The French lifetime extension program was estimated by EDF itself to 49.4 billion euros for 61.4 GWe, that is to say 804 million euros by MWe (961 million USD). However, the Cour des comptes (French audit office) criticized this estimation as overly optimistic and suggested a cost of 100 billion euros for the whole program. Furthermore, lifetime extension, even if granted, may actually prove growingly uncompetitive with the implementation of new renewable capacities whose costs keep falling. In the last years, lowest unsubsidized bids for solar and wind energy in the USA proved cheaper than mere nuclear operating costs (See this graph from Schneider et al., 2019 : https://www.worldnuclearreport.org/IMG/pdf/figure_51_nukecc-prices.pdf ; see also Amory B. Lovins, Does Nuclear Power Slow or Speed Climate Change?, Forbes, November 2019). As a result, some reactors of the nuclear fleet were taken off the grid in the last year (See this graph from Schneider et al., 2020 : https://www.worldnuclearreport.org/IMG/pdf/wnisr2020-figure44-nuke-us-earlyretirements.pdf). Others are currently relying on subsidies to keep operating (Schneider et al., 2020).	Rejected. The cost ranges are referenced. The reference relies on the direct contributions on generation cost data from the governments of both OECD and non-OECD countries. It is also reviewed by Expert Group consisting of experts from government, academia and industry	Charlotte MIJEON	Réseau "Sortir du nucléaire" (organiszation affiliated to the French Climate Action Network)	France
81913	35	47	36	2	Lifetime extensions are significantly cheaper but also incurre very high risks for nuclear plants which were not built for the extended lifetimes. It should be added that these relatively 'cheap' extensions are related to very high risks for human health, the environment and the economy.	Rejected. The reviewer does not provide supporting literature.	Anke Herold	Oeko-Institut e.V.	Germany
78507	35	48	36	2	The overnight cost of lifetime extensions is estimated in the range of USD 390 - 630/kWe for Europe and North America. The cost of electricity from these powerplants is USD 30–36/MWh (OECD IEA NEA 2020).	Accepted. Text revised.	Tomaž Žagar	Faculty for Energy Technology, University of Maribor	Slovenia
6039	35				Some reactors in the US have had their license extended to 80 years.	Accepted. Will be added if space allows. Also, text was revised to "first extension" meaning that subsequent extensions might be possible	Adam Burak	University of Michigan	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
6041	35				I am surprised there is no discussion on Gen IV reactors or spent nuclear fuel reprocessing. These are important concepts to integrate when considering the overall sustainability.	Taken into account. These subjects are important, but not crucial for near term deployment.	Adam Burak	University of Michigan	United States of America
4803	36	3	36	4	NuScale current estimate: US$8,500/kW*, up from 2003-projection of US$(2019) 1,700/kW NuScale 2008 projection was electricity generation by 2015-16; the current projection is now 2029-30.	Noted.	Aviel Verbruggen	University of Antwerp	Belgium
4805	36	3	36	7	on the SMR future: " announced capital costs"; "expected to make these technologies competitive with other low-carbon options by 2030 (medium confidence)". "Announced" and "expected" are proven to be overly optimistic in nuclear power construction; all numbers over the past decade on construction cost and time overrun are such that optimism is deceiving the readership. "Medium confidence" is a score unlikely assigned on a factual basis.	Taken into account. The text has been revised and referenced.	Aviel Verbruggen	University of Antwerp	Belgium
42983	36	3	36	3	The dollar amount appears to be missing	Noted	Kurt Kornelsen	Ontario Power Generation	Canada
48119	36	3	36	7	The Nuscale reactor costs went up and its completion proposed date delayed 3 more years to 2030: https://www.sciencemag.org/news/2020/11/several-us-utilities-back-out-deal-build-novel-nuclear-power-plant	Noted	Mark Jacobson	Stanford University	United States of America
51093	36	3	36	4	"The first U.S. small-scale nuclear power project NuScale announced a capital cost of less than USD 5,100/kWe, which would not be competitive in the U.S. given current natural gas prices": This statement is factual but is misleading and should be revised. Indeed, no power tehchnology is competitive against gas turbines in the US today. Even solar PV and wind energy without storage are barely competitive (but surprising, this is not mentioned in the sections on solar and wind). So what is the purpose of this statement for nuclear?	Accepted. Text revised.	Eric PROUST	European Nuclear Society (ENS)	France
61783	36	3	36	7	The provided cost estimate and the subsequent implied inability of NuScale plant to compete with natural gas is outdated. NuScale has revised their cost-estimate since the referred (Capellán-Pérez et al. 2017) came out. The most recent capital cost is $3466/kW (https://www.nuscalepower.com/benefits/cost-competitive). A comparison with CCGT plant shows that NuScale plant will be cost competitive if the discount rate is 5% or less (see https://thebreakthrough.org/issues/energy/nuscale-vs-gas). Even when accounting for lower-than-reference gas prices, the plant will be competitive at discount rate of 3%. Finally, if recent EU-level carbon prices (at the EU emissions trading system) are enacted, the NuScale plant becomes competitive with CCGT even at high discount rates: an 8-10% rate is competitive with low gas price and carbon priced at $30-40/ton. The paragraph should be changed accordingly, to explicitly mention that "the NuScale plant is expected to be cost-competitive".	Accepted. Text revised	Rauli Partanen	Think Atom	Finland
65813	36	3	36	7	The provided cost estimate and the subsequent implied inability of NuScale plant to compete with natural gas is incorrect and requires a revision. The company NuScale estimates the capital cost to be $3466/kW not $5100/kW (see https://www.nuscalepower.com/benefits/cost-competitive). A proper comparison with CCGT plant demonstrates that NuScale plant will be cost competitive if the discount rate is 5% or less (see https://thebreakthrough.org/issues/energy/nuscale-vs-gas). Even when accounting for lower-than-reference gas prices, the plant will be competitive if the discount rate remains 3%. COMMENT CONTINUES.	Accepted. Text revised	Eero Hirvijoki	Aalto University	Finland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
65815	36	3	36	7	COMMENT CONTINUTES: Both these rates are typical for public utilities. Finally, the analysis shows, that if carbon policies are enacted, the NuScale plant becomes competitive with CCGT even at high discount rates and carbon prices similar to what already exists within the EU emissions trading system: an 8-10% rate is competitive with low gas price and carbon priced at $30-40/ton, a rate already observed in EU at $46/ton as of Feb 22, 2021. The paragraph should be changed accordingly, to explicitly mention that "the NuScale plant is expected to be cost-competitive".	Accepted. Text revised	Eero Hirvijoki	Aalto University	Finland
76403	36	3	36	7	The value mentioned of US$5,100/kWe is incorrect by a substantial margin.Updates to the costs of small nuclear power plants: 1.Nuscale now quote their 1st of a kind to be US$3,389/kw and nth of a kind to be US$2,805/kw 2.General Electric Hitachi is quoting US$3,000/kw for first of a kind and US$2,500/kw for nth of a kind This would make a system using nuclear energy cost competitive with a system using gas plus VRE and significantly more reliable and have lower emissions.	Accepted. Text revised	Robert Parker	Nuclear for Climate Australia	Australia
17351	36	4	36	4	"The first U.S. small-scale nuclear power project NuScale announced a capital cost of less than USD 4 5,100/kWe, which would not be competitive in the U.S. given current natural gas prices…" Nothing is competitive to gas turbines in US today. Even solar PV and wind WITHOUT storage are barely competitive. I might be wrong but I hope that the key goal of IPCC report is to eliminate fossil and not nuclear.	Accepted. Text revised	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
78509	36	4	36	4	Correct USD 5100 per kWe to USD 3600 per kWe. NuScale has an estimated Nth-of-a-kind (NOAK) overnight capital cost of approximately $3,600/KW, backed by our AACE Class IV cost estimate (https://www.nuscalepower.com/newsletter/nucleus-spring-2020/featured-topic-cost-competitive)	Accepted. Text revised	Tomaž Žagar	Faculty for Energy Technology, University of Maribor	Slovenia
80507	36	4	36	5	The reference “Capellan-Perez et al. 2017” is on “Assessing vulnerabilities and limits in the transition to renewable energies: Land requirements under 100% solar energy scenarios” and does not seem to fit here to the comparison of NuScale and US gas prices.	Accepted. Thank you. Text revised	Moritz Riede	University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
80509	36	4	36	4	Update sentence to include the recent renewable prices --> “which would not be competitive in the U.S. given current natural gas prices (US$59/MWh) as well as the cost of electricity from solar ($37/kWh) and wind ($40/kWh).” (https://www.lazard.com/media/451419/lazards-levelized-cost-of-energy-version-140.pdf page 8) (Note: given delays and raising cost several US utilities have backed out of a deal to build a NuScale power plant, see https://dx.doi.org/10.1126/science.abf5797)	Accepted. Text revised	Moritz Riede	University of Oxford	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
1559	36	5	36	7	There is no way that "medium confidence" would be assigned to nuclear plant being expected to make nuclear "competitive with other low-carbon options by 2030" by the energy community at large. I personally would assign "high confidence" to the inverse statement that nuclear would not be competitive by this date. My view would be supported by the IEA with 2040 LCOE for nuclear estimated as USD60-110/MWh across the 4 major regions where data are presented (US, EU, China, India). IEA estimates for solar and wind across these 4 regions for 2040 are USD25-35/MWh and USD35-50/MWh, respectively (down considerably from IEA 2040 estimates of USD55-105/MWh and USD50-90/MWh made only 2 years earlier in 2018 - with these IEA 2040 estimates made only in 2018 higher than recent IEA 2020 estimates of actual 2020 costs!! - with the IEA historically grossly underestimating rates of uptake and cost reduction for renewables, while tending to overestimate for nuclear). The IEA also calculates a VALCOE (value-adjusted LCOE) that increases the latter projections to USD40-65/MWh and USD40-60/MWh, with no increase for nuclear, as is the tradition. One might have thought the IEA would be aware that, in Japan, 1GW of pumped hydro was installed more or less in parallel with every 2GW of nuclear to provide load matching (since nuclear there operates only "off" or "on") or that in France, with its "load following" nuclear, hydro and gas are actually used for load following, presumably because these are cheaper options for this role (offsetting additional nuclear maintenance costs). This implies ancillary storage or generators are required to get the LCOEs ofter quoted from nuclear, similarly to the situation for renewables, with asssociated additional costs traditionally neglected for nuclear but nonetheless real.	Accepted. Text revised.	Martin Green	UNSW Sydney	Australia
3177	36	5	36	7	"Cost-cutting opportunities, for SMRs and GEN III/III+ reactors, such as design standardisation and innovations in construction approaches, are expected to make these technologies competitive with other low-carbon options by 2030 (medium confidence)." What is the evidence? Low confidence seems more appropriate.	Accepted. Text revised.	Philippe Quirion	CNRS	France
51095	36	5	36	6	XX	Noted	Eric PROUST	European Nuclear Society (ENS)	France
55683	36	5	36	7	This is an odd statement because 57 GWe of new nuclear generation came online in the last decade, providing an amount of electricity that is at least half as much as that provided by new solar. This indicates that nuclear is competing with solar today. Further, at low levels of penetration, solar and wind have low curtailment and so are more valuable. With deeper decarbonization, the reliable nuclear power becomes more valuable relative to non-dispatchable variable generation. See https://www.iaea.org/newscenter/news/iaea-releases-2019-data-on-nuclear-power-plants-operating-experience Suggest clarifying distinction between current and near future, as follows: "Conventional nuclear power is competing with other low-carbon technologies today. Cost-cutting opportunities, for SMRs and GEN III/III+ reactors, such as design standardisation and innovations in construction approaches, are expected to make these newer technologies competitive with other low-carbon options by 2030 (medium confidence)."	Noted	Government of United States of America	U.S. Department of State	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
76623	36	5	36	7	This sentence appears to be overly optimistic and at odds with the current cost dynamics of both nuclear power and renewable energies, particularly regarding SMRs. A recent (March 2021) report issued by Öko-Institut for the German Federal Office for the Safety of Nuclear Waste Management on SMRs states that significant cost savings due to greater modularity have not been observed in past reactor developments and are not expected in the future. It highlights the fact that specific construction costs are higher for SMRs than for large nuclear plants due to the loss of economics of scale. According to this report, about 3000 SMR would have to be produced to make SMR production feasible. Thus the structural cost disadvantage of low-power reactors is not expected to be compensated by learning or mass effect. (Sicherheitstechnische Analyse und Risikobewertung einer Anwendung von SMR-Konzepten(Small Modular Reactors), urn:nbn:de:0221-2021030826028). Moreover, developing SMR would increase the risks related to proliferation issues.	Taken into account. The text was added that per unit of energy SMRs can be more expensive than large reactors.	Charlotte MIJEON	Réseau "Sortir du nucléaire" (organiszation affiliated to the French Climate Action Network)	France
81915	36	5	36	7	There is no reference provided for the statement that the small-scale reactor technologies are expected to be competitive with other low-carbon options by 2030. Please provide at least several scientific references or delete this statement. The specific construction costs per MW are currently substantially higher for small nuclear reactors than for renewable energy and mass production to significantly cut costs would require potentially hundreds and thousands of small scale reactors which are unlikely to be built by 2030 guven that they are all in explorative stages. The small-scale reactors also constitute a considerably increased risk for nuclear proliferation.	Taken into account. The reference is added.	Anke Herold	Oeko-Institut e.V.	Germany
995	36	6			remove comma	Accepted. Text revised	Alok Dhaundiyal	Szent Istvan University	Hungary
9173	36	8	36	15	Reformulate or delete: "Nuclear power is attended by a range of environmental and ecological impacts (high confidence)" since this is valid only for the accidents.	Accepted. Text revised.	Marin Constantin	RATEN ICN	Romania
12199	36	8	36	9	"Nuclear power is attended by a range of environmental and ecological impacts". While we do appreciate the impartial nature of the text and the factual information given on waste and water usage, we believe that the phrase creates the impression of damaging effect while nuclear has the opposite effect, of reducing CO2 emissions. We propose the following rephrase "The benefits of nuclear power outweight the risks to environment"	Accepted. Text revised.	Lavinia Rizea	SN Nuclearelectrica SA	Romania
15529	36	8	36	8	Exclude the sentence "Nuclear power is attended by a range of environmental and environmental impacts (high confidence)" as untrue. The impact of nuclear power on the environment is less than, for example, coal and can be compared to solar and wind power, given all aspects of the energy system lifecycle. https://www.world-nuclear.org/information-library/energy-and-the-environment/nuclear-energy-and-sustainable-development.aspx, Essam El-Hanawi Environmental Impact Survey, IAEA Bulletin, Book 20, Number 2, Nuclear Power and Sustainable Development, Vienna 2016.	Accepted. Text revised	Vladimir Kucinov	National Research Nuclear University "MEPHI" (Moslow Enginiring Physical Institute)	Russian Federation

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
17173	36	8	36	15	Several comments are to be made regarding the text between lines 8 and 15 : - there seems to be a confusion between the impacts of normal operation of a nuclear power plant and the impacts in the situation of a major nuclear accident (also impacts in case of major accidents seems to be not detailed for oil/gas). In normal operation, there is very little to no impact on environment. - the first sentence "Nuclear power is attended by a range of environmental and ecological impacts (high confidence)" is contradicting the following sentences in the same paragraph, especially lines 15-16 and 25-26 (clear contradiction for ecological impact). - several new GEN III designs of reactors are reducing the risk of accidents and of impacts on the environment, and not only passive designs. Thus, the text could be reorganized/amended as follows: "Despite low probabilities, the potential for major nuclear accidents exists, and the radiation exposure impacts could be very large and long-lasting (Steinhauser et al. 2014). New reactor designs, including the ones that include a wide range of passive safety systems, have nevertheless further reduced the risk of such accidents (high confidence). The (normal) activity of a nuclear reactor results in radioactive waste production entailing strictly controlled disposal. On a global scale, roughly 421 ktons of spent nuclear fuel have been produced since 1971 (IEA 2014). Out of this volume, 2–3% is high-level radioactive waste (HLW), which presents challenges in terms of radiotoxicity and longevity and requires permanent disposal". [The following text starting in the middle of line 15 remain unchanged.]	Accepted. Text revised accordingly.	Government of Poland	Ministry of Environment, Department of Air Protection and Climate	Poland
17353	36	8	36	8	"Nuclear power is attended by a range of environmental and ecological impacts (high confidence)." Exactly the same statement can be written for every known source of energy. But I find it only in nuclear section. I suggest to rephrase: "Like all other energy sources, nuclear power is attended by a range of environmental and ecological impacts (high confidence)." or delete.	Accepted. Text revised.	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
18841	36	8	36	15	When nuclear reactor is in ordinary operation there are no such impacts (on environment) as in case of nuclear accident. Generation III+ that is currently being build in some countries reduce the risk of an accident significantly.	Noted	Tomáš Martanovič	Ministry of Industry and Trade	Czech Republic
19647	36	8	36	15	The first statement "Nuclear power is attended by a range of environmental and ecological impacts (high confidence)" is contradicting the following sentences in the same paragraph, especially lines 15-16 and 25-26 (clear contradiction for ecological impact). We propose to amend the text as follows: New reactor designs (ADD- with wide range of passive safety systems), have nevertheless further reduced the risk of such accidents (high confidence). (ADD- The (normal) activity of a nuclear reactor) results in radioactive waste (ADD- production) entailing strictly controlled disposal.	Accepted. Text revised.	Government of Slovakia	State Advisor, Climate Change Policy Department Ministry of the Environment	Slovakia

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
20977	36	8	36	15	Please find several comments regarding the text between lines 8 and 15 : - there seems to be a confusion between the impacts of normal operation of a nuclear power plant and the impacts in the situation of a major nuclear accident (also impacts in case of major accidents seems to be not detailed for oil/gas). In normal operation, there is very little to no impact on environment. - the first sentence "Nuclear power is attended by a range of environmental and ecological impacts (high confidence)" is contradicting the following sentences in the same paragraph, especially lines 15-16 and 25-26 (clear contradiction for ecological impact). - several new GEN III designs of reactors are reducing the risk of accidents and of impacts on the environment, and not only passive designs. Thus, the text could be reorganized/amended as follows: "Despite low probabilities, the potential for major nuclear accidents exists, and the radiation exposure impacts could be very large and long-lasting (Steinhauser et al. 2014). New reactor designs, including the ones that include a wide range of passive safety systems, have nevertheless further reduced the risk of such accidents (high confidence). The (normal) activity of a nuclear reactor results in radioactive waste production entailing strictly controlled disposal. On a global scale, roughly 421 ktons of spent nuclear fuel have been produced since 1971 (IEA 2014). Out of this volume, 2–3% is high-level radioactive waste (HLW), which presents challenges in terms of radiotoxicity and longevity and requires permanent disposal". [The following text starting in the middle of line 15 remain unchanged.]	Accepted. Text revised accordingly.	Government of France	Ministère de la Transition écologique et solidaire	France
31469	36	8	36	15	Several new Generation III reactor designs further reduced the risk of such accidents	Noted	Carolina Ahnert	Universidad Politécnica de Madrid	Spain
37681	36	8	36	18	In line 8, the text reads, "Nuclear power is attended by a range of environmental and ecological impacts", and has no reference. In lines 15 to 18, one gets correct impression as the references are cited. It will be appropriate to moderate the text in line 8.	Accepted. Text revised	Ravi B Grover	Homi Bhabha National Institute	India
51097	36	8	36	15	The first sentence of the paragraph: "Nuclear power is attended by a range of environmental and ecological impacts (high confidence)" should be reworded or deleted as it is inconsistent with/contradicted by the following sentences in the same paragraph, especially lines 15-16 and 25-26 (clear contradiction for ecological impact)	Accepted. Text revised.	Eric PROUST	European Nuclear Society (ENS)	France
51099	36	8	36	15	The sentence "New passive reactor designs have nevertheless further reduced the risk of such accidents (high confidence)" should be 1/ replaced by "several new Generation III reactor designs further reduced the risk of such accidents (high confidence)" (no only passive reactors designs achieve this result, see [1]) 2/ and moved after "(Steinhauser et al.2014)" as "such accidents'' relates to "major nuclear accidents" while the beginning of the paragraph relates to normal operation of nuclear plants, not to major accident situations [1] EPR Reactor Project Safety https://www.asn.fr/annual_report/2006/PDF/EPR.pdf	Accepted. Text revised	Eric PROUST	European Nuclear Society (ENS)	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
64129	36	8	36	9	The sentences "Nuclear power is attended by a range of environmental and ecological impacts(high confidence). New passive reactor designs have further reduced the risk of such accidents (high confidence)". need to be rephrased. i.e., "Owing to possibility of major nuclear accidents, nuclear power is attached by a range of environmental and ecological impacts(high confidence). . New passive reactor designs, having enhanced and additional safety features and systems have further reduced the risk of such accidents (high confidence)".	Accepted. Text revised	Ghulam Rasul Athar	Pakistan Atomic Energy Commission	Pakistan
64241	36	8	36	15	Sorry – the potential for major accidents exists not only in the nuclear sector. Beginning in the early 1980s, a number of serious major incidents occurred in the petroleum and chemical industries involving highly hazardous materials, which resulted in considerable numbers of fatalities and injuries and significant property losses. These incidents provided the impetus for government agencies, labour organizations and industry associations throughout the world to develop and implement codes, regulations, procedures and safe work practices directed toward the elimination or mitigation of these undesirable events, through the application of the principles of process safety management. A list of industrial disasters is provided in Wikipedia, covering several sectors, such as defense industry, energy industry, food industry, manufacturing industry, mining industry and other industrial disasters (e.g. Bhopal in India - estimates of the death toll range from 3700 to 16,000) - https://en.wikipedia.org/wiki/List_of_industrial_disasters . see also Wikipedia "list of accidents and disasters by death toll": https://en.wikipedia.org/wiki/List_of_accidents_and_disasters_by_death_toll The "challenges associated with potential major nuclear accidents" are addressed in the European Union through the implementation of national policies via binding Euratom legislation (one of the most advanced legislation in the nuclear field for more than fifty years, including plant specific emergency operating procedures /EOPs/ and severe accident management guidelines(/SAMGs/) - see "European Commission Revised Euratom Safety Directive establishing a Community framework for the nuclear safety of nuclear installations" (Council Directive 2014/87/Euratom of 8 July 2014) - https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ:L:2014:219:TOC	Noted	Georges VAN GOETHEM	Royal Academy of Overseas Sciences (ARSOM - KAOW)	Belgium
77233	36	8	36	8	Having nuclear minimal GHG emissions, negligible radioactivity releases, and minimal amount of generated waste, it is not clear to which environmental and ecological impacts the statement refers to with "high confidence". In fact, in lines 15-16 the opposite is written: "Nuclear energy is generally found to be favorable regarding [...] ecological impacts". If it refers to accidents (as the following sentence suggests), 1) "attended" is wrong; 2) the situation of the red forest near Chernobyl demonstrates the opposite: it is one of the most amazing natural reserves in the world [https://www.calvertjournal.com/features/show/5896/chernobyl-exclusion-zone-wildlife]. It is recommended to replace this sentence with "Albeit power plants have redundant safety provisions which reduce the likelihood of accidents, and containment barriers to mitigate any potential release, nuclear power suffers from poor public acceptance, driven by the perception of the risk." Or even deleted, since the same point is touched again few lines below.	Rejected. Text refers to the impacts under normal operation.	Giacomo Grasso	ENEA	Italy

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
78501	36	8	36	8	"Nuclear power is attended by a range of environmental and ecological impacts (high confidence)." Exactly the same statement can be written for every known source of energy. Rephrase to: "Like all other energy sources, nuclear power is attended by a range of environmental and ecological impacts (high confidence)." or delete.	Accepted. Text revised	Tomaž Žagar	Faculty for Energy Technology, University of Maribor	Slovenia
15531	36	9	36	9	Replace the words "nevertheless further reduced the risk of such accidents" with "reduced the risk on severe nuclear accidents" as more contextual	Accepted. Text revised	Vladimir Kucinov	National Research Nuclear University "MEPHI" (Moslow Enginiring Physical Institute)	Russian Federation
79621	36	9			suppress such in "such accidents", because no accident are mention beforehand.	Accepted. Text revised	Marc Daras	CentraleSupelecAlumni	France
4807	36	10	36	10	Uranium mining as well as decommissioning of all facilities in the nuclear fuel chain entails significant amounts of radioactive wastes.	Rejected. Much of the obeserved environmental and health impacts from uranium mining are from legacy operations rather than state-of-the-art facilities. See: https://www.jstor.org/stable/24385190, see also https://ec.europa.eu/info/sites/default/files/business_economy_euro/banking_and_finance/documents/210329-jrc-report-nuclear-energy-assessment_en.pdf	Aviel Verbruggen	University of Antwerp	Belgium
997	36	11			use SI unit (Mg) throughout the report	Noted	Alok Dhaundiyal	Szent Istvan University	Hungary
4809	36	11	36	11	"roughly 421 ktons of spent nuclear fuel have been produced since 1971 (IEA 2014)" . Two comments: 421 ktons = 421 million kg and this is a reader friendly unit. Second: over which period? Since 1971 to … (the IEA source dates from 2014); the right number of years should be mentioned and the information should be updated for relevance in 2021.	Noted	Aviel Verbruggen	University of Antwerp	Belgium
55685	36	11	36	13	Long-term management can work for a while until political conditions allow creation of permanent disposal. Suggest adding the word "ultimately": "Out of this volume, 2-3% is high-level radioactive waste (HLW), which presents challenges in terms of radiotoxicity and longevity and ultimately requires permanent disposal." As it stands, the unimproved sentence could get used to argue that because nuclear requires permanent disposal and there is no permanent disposal, there can be no nuclear. This is a policy prescription that the IPCC should not make, even if it is a good policy prescription.	Taken into account: the text has been rephrased into "ultimately entails permanent disposal"	Government of United States of America	U.S. Department of State	United States of America
4811	36	13	36	15	"Furthermore, despite … long-lasting." Peculiar and confusing way to talk about the risks of nuclear accidents (for example: in "major nuclear accidents" the "radiation exposure impacts" could be very large – which impacts precisely? Reference to the example of Fukushima, and independent references are needed. Provide insight in the real risks as assessed by the global insurance companies. A good proxy of the costs of risks are the insurance premiums paid for full indemnity when the low probability events realize. In 2011, Versicherungsforen Leipzig attempted an estimation of the height of the premium to charge on nuclear kWh generated. Dependent on the expected costs of the damage of accidents and the duration of charging a risk premium on top of the regular costprice in 2011, following numbers were found: for 100 year payments: 0,139 Euro/kWh to 2.36 Euro/kWh; for a manageable payment over 10 years the premiums fall in the range 3.96 Euro/kWh to 67.3 Euro/kWh.	Taken into account. Relevant but can not be included due to space limitations.	Aviel Verbruggen	University of Antwerp	Belgium

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
17355	36	13	36	13	"high-level radioactive waste ... requires permanent disposal." I suggest to add a sentece. "Existing technologies of HLW management are based on controled storage of the waste that can last for centuries, which is beyond the time scales of the man-made climate changes." (I do not have a journal reference, but Slovenian nuclear power plant has just ordered spent fuel casks that will last at least 100 years.)	Taken into account. Will be considered only if space allows.	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
51101	36	13	36	13	"Furthermore, despite low probabilities,": delete "furthermore" as the problematics of major accidents is unrelated to nomrmal operation.	Accepted. Text revised	Eric PROUST	European Nuclear Society (ENS)	France
61785	36	13	36	15	"Furthermore, despite low probabilities, the potential for major nuclear accidents exists, and the radiation exposure impacts could be very large and long-lasting (Steinhauser et al. 2014)." This is a speculative statement and implies wrongly that the potential public health consequences “could be very large”. The radiation exposure impacts have already been found to be negligible for example in the triple-meltdown accident of Fukushima. Instead cite IAEA on the Fukushima accident: "No observations of direct radiation induced effects in plants and animals have been reported, although limited observational studies were conducted in the period immediately after the accident. There are limitations in the available methodologies for assessing radiological consequences, but, based on previous experience and the levels of radionuclides present in the environment, it is unlikely that there would be any major radiological consequences for biota populations or ecosystems as a consequence of the accident" Part 1/2	Taken into account. Relevant but can not be included due to space limitations.	Rauli Partanen	Think Atom	Finland
61787	36	13	36	15	Part 2/2. (IAEA, 2015, ISBN: 978-92-0-107015-9, https://www.iaea.org/publications/10962/the-fukushima-daiichi-accident). Also mention that several studies have reported how wildlife flourishes at the Chernobyl Exclusion Zone largely due to absence of human activity (Deryabina et al., 2015, https://doi.org/10.1016/j.cub.2015.08.017; Lerebours et al., 2018, https://doi.org/10.1021/acs.est.8b02378; UNEP https://www.unep.org/news-and-stories/story/how-chernobyl-has-become-unexpected-haven-wildlife).	Taken into account. Relevant but can not be included due to space limitations.	Rauli Partanen	Think Atom	Finland
65817	36	13	36	15	"Furthermore, despite low probabilities, the potential for major nuclear accidents exists, and the radiation exposure impacts could be very large and long-lasting (Steinhauser et al. 2014)." This is a speculative statement discredited by reseach. For example, the IAEA report on the Fukushima accident states that "No observations of direct radiation induced effects in plants and animals have been reported, although limited observational studies were conducted in the period immediately after the accident. There are limitations in the available methodologies for assessing radiological consequences, but, based on previous experience and the levels of radionuclides present in the environment, it is unlikely that there would be any major radiological consequences for biota populations or ecosystems as a consequence of the accident" (IAEA, 2015, ISBN: 978-92-0-107015-9, https://www.iaea.org/publications/10962/the-fukushima-daiichi-accident). COMMENT CONTINUES	Taken into account. Relevant but can not be included due to space limitations. The reference mentioned by the reviewer refers to Fukushima Daiichi accident only.	Eero Hirvijoki	Aalto University	Finland
65819	36	13	36	15	COMMENT CONTINUES: Also it would be worth to mention the studies that report how wildlife flourishes at the Chernobyl Exclusion Zone largely due to absence of human activity (Deryabina et al., 2015, https://doi.org/10.1016/j.cub.2015.08.017 ; Lerebours et al., 2018, https://doi.org/10.1021/acs.est.8b02378 ; UNEP https://www.unep.org/news-and-stories/story/how-chernobyl-has-become-unexpected-haven-wildlife).	Taken into account. Relevant but can not be included due to space limitations.	Eero Hirvijoki	Aalto University	Finland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
76625	36	13	36	15	Major accidents are not just a probability, but a reality (Chernobyl, Fukushima, Mayak…)	Noted	Charlotte MIJEON	Réseau "Sortir du nucléaire" (organiszation affiliated to the French Climate Action Network)	France
78503	36	13	36	13	"high-level radioactive waste ... requires permanent disposal." Correct requires long-term repository. All HLW is managed well and is stored withouth any direct impacts on environment.I suggest to add a sentece. "Existing technologies of HLW management are based on controled storage of the waste that can last for centuries, which is beyond the time scales of the man-made climate changes."	Rejected. The reviewer does not provide supporting literature.	Tomaž Žagar	Faculty for Energy Technology, University of Maribor	Slovenia
9175	36	14	36	15	Please reformulate "the radiation exposure impacts could be very large and long-lasting". This is nor valid for new systems, for example Generation-IV or SMR where the emergency zone is limited to the site.	Rejected. The reviewer does not provide supporting literature.	Marin Constantin	RATEN ICN	Romania
999	36	15			check spelling	Noted	Alok Dhaundiyal	Szent Istvan University	Hungary
4813	36	15	36	18	"Nuclear energy is generally found to be favorable regarding land occupation": Comments: are long-time losses of human habitats considered, e.g., Chernobyl, Fukushima? "… and ecological impacts". Comments: only local biodiversity impacts of uranium mining? Also, building-integrated solar has zero land occupation and vertical solar panels dramatically reduce land occupation.	Rejected. The reviewer does not provide supporting literature. Please see https://ec.europa.eu/info/sites/default/files/business_economy_euro/banking_and_finance/documents/210329-jrc-report-nuclear-energy-assessment_en.pdf	Aviel Verbruggen	University of Antwerp	Belgium
20979	36	15	36	15	Please consider removing "generally", as nuclear energy is favorable regarding land occupation	Accepted. Text revised	Government of France	Ministère de la Transition écologique et solidaire	France
51103	36	15	36	15	"is generally found to be": delete "generally found to be". I do not know of people/ of any reference having argued against this fact	Accepted. Text revised	Eric PROUST	European Nuclear Society (ENS)	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
76627	36	15	36	16	Land occupation issue should also take into account long-term considerations and reversibility issues. While a wind or solar farm do require some space (but are not systematically uncompatible with concomitent use for agricultural purpose, e.g. agrivoltaics), their decommissioning entails no major technical issue. On the contrary, decommissioning a nuclear plant is a long-terme process that requires decades, sufficient funding and a major concern for safety issues, contamination risk for workers and long-terme activated waste management. According to the World Nuclear Industry Status Report (Schneider et al., 2020) only 20 out of the 189 closed reactors have been decommisioned so far and only 10 returned to greenfield. This consideration also applies to operating and former uranium mines. As an example, the cleaning up of the former Wismut mine in Germany has been ongoing since the 90s, has costed 6,8 billion euros so far and will last for 30 further years. Many uranium mining and tailing sites remain undecommissioned in the world, involving safety and health issues for the population. Furthermore, land use consideration should also take into account the broad areas made uninhabitable or insuitable for agricultural purpose due to previous nuclear accidents (Mayak, Chernobyl, Fukushima). A simulation made by the Swiss institute Biosphère shows that depending on weather conditions, a major accident in either a Swiss nuclear power plant or the neighbouring French NPP Le Bugey could result in the contamination of 16,000 to 37,000 km2 of pastures or fields (Piguet, Frédéric-Paul. Eckert, Pierre. Knüsli, Claudio. Deriaz, Bastien. Wildi, Walter. Giuliani, Gregory. 2019. "Modeling of a Major Accident in Five Nuclear Power Plants From 365 Meteorological Situations in Western Europe and Analysis of the Potential Impacts on Populations, Soils and Affected Countries". Institut Biosphère. Strategic Study n°2. Final version B, 27 August 2019. 42 p.https://institutbiosphere.ch/wa_files/EUNUPRI-2019v01.pdf)	Rejected. Only normal operation of nuclear reactors is included in LCA analysis and different land occpation metrics. Please see: https://ec.europa.eu/info/sites/default/files/business_economy_euro/banking_and_finance/documents/210329-jrc-report-nuclear-energy-assessment_en.pdf	Charlotte MIJEON	Réseau "Sortir du nucléaire" (organiszation affiliated to the French Climate Action Network)	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
76629	36	15	36	17	Picturing nuclear power as favourable regarding ecological impacts means ignoring research documenting the impacts on fauna and flora of radiation caused by nuclear accidents. See for example Nesterenko, AV ; Nesterenko, VB ; Yablokov, AV, 2009, Chernobyl: consequences of the catastrophe for people and the environment, Annals of the New York Academy of Sciences, 1181 DOI: 10.1111/j.1749-6632.2009.04819.x Mousseau T, Møller, A, 2014, Genetic and Ecological Studies of Animals in Chernobyl and Fukushima, Journal of Heredity, Volume 105, Issue 5, September-October 2014, Pages 704–709, https://doi.org/10.1093/jhered/esu040 Pyastolova OA, Vershinin VL, Trubetskaya EA, Gatiyatullina EZ. 1996. Utilization of amphibians in bioindication research on territories of the Eastern Urals radioactive trace. Russian Journal of Ecology 27:361–365. Mousseau T, Møller, A, 2020, Plants in the Light of Ionizing Radiation: What Have We Learned From Chernobyl, Fukushima, and Other “Hot” Places?r, Frontier Plant Science. | https://doi.org/10.3389/fpls.2020.00552 Beside, the reference to Brooks and Bradshaw is highly controversial. Several academics indicated major flaws in their approach (such as ignoring existing litterature on the subject, not taking into account total costs and providing questionable information about "new generation reactors"), underlining that Brooks and Bradshaw's personal preference for nuclear power may have biased their results. See Henle, K., Gawel, E, Ring, I, Strunz, S, 2016, Promoting nuclear energy to sustain biodiversity conservation in the face of climate change: response to Brook and Bradshaw 2015, Conservation Biology, https://doi.org/10.1111/cobi.12691 See also Hendrickson, O, 2016,Nuclear energy and biodiversity conservation: response to Brook and Bradshaw 2015 https://doi.org/10.1111/cobi.12693	Rejected. There is a sentence in the text "despite low probabilities, the potential for major nuclear accidents exists, and the radiation exposure impacts could be very large and long-lasting "	Charlotte MIJEON	Réseau "Sortir du nucléaire" (organiszation affiliated to the French Climate Action Network)	France
17357	36	17	36	17	"...the upstream nuclear life cycle (i.e., mining, tailings)." Problem of mining is exposed for nuclear but not for any other energy source. requirements for mining are much lower per TWh of nuclear energy thatn per TWh of any other energy: wind, solar, hydro, ..fossil,.... http://environmentalprogress.org/the-complete-case-for-nuclear My recommendation: to add a Table that reviews requirement for bulk materials per MWh of energy for all sources.	Taken into account. Relevant, but unfortunately no space to add any table or figure.	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
24673	36	17	36	18	Given that nuclear requires a significantly lower volume of raw materials compared to other energy sources, we question why reference is made here to mining impacts (eg tailings). If this is to be highlighted as an issue for nuclear, we would recommend highlighting it also for raw material intensive power technologies such as solar	Taken into account. It is true that with the exception of higher levels of radioactivity associated with uranium ore, uranium mining shares many environmental aspects with mining operations of other minerals (including tailings and hazardous materials). Will consider removing it if other technologies are not mentioning it.	Ann Jessica Johnson	FORATOM (European Atomic Forum)	Belgium
75749	36	17	36	18	The claim that uranium mining can impact local biodiversity is out of order and unsupported by evidence. The same statement can be given for minning of materials needed for production of solar cells. The references indicate that uranium minning is one of the most regulated minning operations under strict control, to cite "Uranium mining remains controversial principally because of legacy environmental and health issues created during the early phase of the industry. Today, uranium mining is conducted under significantly different circumstances and is now the most regulated and one of the safest forms of mining in the world." (OECD NEA report on Managing Environmental and Health Impacts of Uranium Mining, 2014)	Taken into account. It is true that with the exception of higher levels of radioactivity associated with uranium ore, uranium mining shares many environmental aspects with mining operations of other minerals (including tailings and hazardous materials). Will consider removing it if other technologies are not mentioning it.	Krešimir Trontl	University of Zagreb, Faculty of Electrical Engineering and Computing	Croatia

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
85971	36	17	36	18	"the upstream nuclear life cycle (i.e. mining, tailings) can impact biodiversity." This statement is true but it is equally true for the resources required for widespread deployment of solar and wind energy and batteries, with requirements for major expansion of mining for nickel, cobalt, lithium, rare-earth elements, and many others.	Taken into account. It is true that with the exception of higher levels of radioactivity associated with uranium ore, uranium mining shares many environmental aspects with mining operations of other minerals (including tailings and hazardous materials). Will consider removing it if other technologies are not mentioning it.	Government of Australia	Department of Industry, Science, Energy and Resources	Australia
37683	36	18	36	19	In addition to indicating in terms of materila requirements, it will be appropriate to also articulate the same concept in terms of Energy Returned Over Invested (EROI). Please see "Energy and the wealth of nations: An introduction to biophysical economics" by CAS Hall and K Klitgaard, Second edition, Springer, 2018.	Taken into account. EROI is not considered because of controversies around this metrics, and none of technology sections consder it.	Ravi B Grover	Homi Bhabha National Institute	India
61789	36	18	36	19	"Similarly, requirements of bulk materials per unit of energy produced are low (e.g. aluminum, copper, iron, rare earth metals) (Luderer et al. 2019)". Provide a quantitative measure for the adjective "low", i.e., compare the bulk material requirements between nuclear and other low-carbon technologies. A comparison of European Pressurized Reactor (EPR, Supplementary Table 1 in Vidal et al., 2013, https://doi.org/10.1038/ngeo1993 available at: https://static-content.springer.com/esm/art%3A10.1038%2Fngeo1993/MediaObjects/41561_2013_BFngeo1993_MOESM174_ESM.pdf) and median estimates for wind and solar (from Carrara et al 2020, http://dx.doi.org/10.2760/160859) shows that the EPR/nuclear uses roughly 10-times less materials to produce a given amount of electricity, depending on chosen capacity factors and plant lifetimes. This high resource-efficiency is a significant benefit of nuclear, and should be mentioned.	Taken into account. Suggested text wouldn't change the original message. Thank you for the reference.	Rauli Partanen	Think Atom	Finland
65821	36	18	36	19	"Similarly, requirements of bulk materials per unit of energy produced are low (e.g. aluminum, copper, iron, rare earth metals) (Luderer et al. 2019)". Provide a quantitative measure for the adjective "low", i.e., explicitly compare the bulk material requirements between nuclear and other low-carbon technologies. An appropriate source would be the Supplementary Table 1 of (Vidal et al., 2013, https://doi.org/10.1038/ngeo1993) available at https://static-content.springer.com/esm/art%3A10.1038%2Fngeo1993/MediaObjects/41561_2013_BFngeo1993_MOESM174_ESM.pdf	Taken into account. Suggested text wouldn't change the original message. Thank you for the reference.	Eero Hirvijoki	Aalto University	Finland
1001	36	19			check spelling	Noted	Alok Dhaundiyal	Szent Istvan University	Hungary
8917	36	19	36	21	I propose: "Depending on the choice of cooling system (once-through or closed cycle) (Mouratiadou et al. 2016), nuclear power can require almost no water (Jin et al. 2019) or pump significant volumes, which are heated by some degrees and recycled to the water source (Meldrum et al. 2013). When reactors are located on sea-shore, the impact of cooling on the sea water is negligible." See for example "Water use of electricity technologies: A global meta-analysis" Yi Jin Paul Behrens Arnold Tukker Laura Scherera Renewable and Sustainable Energy Reviews Volume 115, November 2019. In fact, the real consumption of water is only the part which turns to low temperature steam (in case of cooling tower). if there is no tower, the net consumption is zero.	Taken into account. The text related to sea-shore will be revised. Thank you for the reference.	Jean-Guy DEVEZEAUX DE LAVERGNE	Université Paris-Dauphine & Société Française d'Energie Nucléaire	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
15533	36	19	36	21	High water consumption is not a unique characteristic of a nuclear power plant, but is typical of all sources of electricity generation using Rankin's thermodynamic cycle. According to EPRI data for 2010, the nuclear power plant required about 850 gallons per MWh, and for a solar thermal power station about 750 gallons per MWh. https://www.world-nuclear.org/information-library/current-and-future-generation/cooling-power-plants.aspx	Noted	Vladimir Kucinov	National Research Nuclear University "MEPHI" (Moslow Enginiring Physical Institute)	Russian Federation
15535	36	19	36	21	Replace the expression "once-through or closed cycle" with "direct or recirculating wet cooling" because in the nuclear energy literature "once-through or closed cycle" refers to the nuclear fuel cycle.	Taken into account. Most literature refers to once-through and closed-loop cooling systems for water use.	Vladimir Kucinov	National Research Nuclear University "MEPHI" (Moslow Enginiring Physical Institute)	Russian Federation
17359	36	20	36	21	"...nuclear power can require large amounts of water..." Very similar amount of cooling water is needed in all thermodynamic processes where heat is converted to electricity: solar CSP, biofuel-to-electricity, waste-to-electricity, (coal/gas-to-electricity). I suggest to remove that point, becaues it is not a problem in my opinion, or to mention it also with other sources (it is mentioned only with CCS technology).	Taken into account: the text has been revised	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
79623	36	20	36	21	two points on this sentence: 1 the volume of water is directly related to phe power delivered, so a coal, gas or biomass PP will need the wame volume of water for the same power. However, it is true that NPP have a lower efficiency (33%) than modern coal PP, thus needing to evacuate more heat per kWh produced. 2. At a global level, once through or cooling tower need the same volume of water for cooling, beacuse in the cooling tower one has direct exchange of latent heat, then evaporation, while on the once through the evaporation will be along the river, while it goes back to its equilibrium temperature. In one case one has a direct uptake of water, while in the second it is differed, but the elevation of temperature may have an impact on the fishes... In conclusion, I do not know what is meant by this sentence, which could be written for any thermal PP.	Taken into account. Agree, but we are discussing here only low carbon technologies. CCS has discussion on it, but not CSP, that is where the comment should go.	Marc Daras	CentraleSupelecAlumni	France
45457	36	21	36	23	Dry cooling of thermal power plants (including nuclear) can be (and actually is) used as an alternative method of cooling. Such method requires no water, as the condenser is cooled with air. Please see eg.: https://doi.org/10.3390/en14051308 and https://doi.org/10.1016/S0065-2717(08)70161-8 THTR-300 was cooled that way, Iran's Isfahan and Saveh were to use dry cooling https://www.osti.gov/servlets/purl/1210198/ Please also see https://www.energy.gov/ne/downloads/cooling-water-issues-and-opportunities-us-nuclear-power-plants	Taken into account. Dry cooling is among options, but very expensive, wouldn't help the economics of nuclear.	Maciej Lipka	National Centre for Nuclear Research	Poland
15537	36	22	36	22	It is a dubious assertion that "... Water intensive inland nuclear power plants may contribute to localized water stress and exacerbate conflicts among competing water uses in those areas (Fricko et al.2016)" because in the case of such placement of NPP, the use of recirculating wet cooling systems is most likely be used.	Taken into account. Text will be revised.	Vladimir Kucinov	National Research Nuclear University "MEPHI" (Moslow Enginiring Physical Institute)	Russian Federation
20981	36	22	36	22	more immune or plain "immune" ?	Accepted. Text will be revised.	Government of France	Ministère de la Transition écologique et solidaire	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
24675	36	22	36	24	Regarding nuclear power plants, it should be noted that it is technically feasible to adapt them in the event of more recurrent drought/water scarcity issues. (see for example the Palo Verde NPP located in the Arizona [US] dessert which uses wastewater)	Noted	Ann Jessica Johnson	FORATOM (European Atomic Forum)	Belgium
51105	36	22	36	22	"more immune": "more" should be deleted since, by location, they are immune to water scarcity	Accepted. Text revised.	Eric PROUST	European Nuclear Society (ENS)	France
51107	36	22	36	24	"On the other end …. (Fricko et al. 2016)": add, before the reference "adaptation in power plant cooling technology can considerably reduce global freshwater withdrawals and thermal pollution" to be consistent with the referenced (Fricko's) paper whose abstrat does not focus on the potential conflicts but, quite the contrary, stresses that adaptation in power plant cooling technology can considerably reduce global freshwater withdrawals and thermal pollution.	Accepted. Will be revised.	Eric PROUST	European Nuclear Society (ENS)	France
20983	36	24	36	24	Interestingly the abstract of the paper that is cited does not focus on the potential conflicts. Conversely, the astract states "We find that water implications vary significantly across scenarios, and that adaptation in power plant cooling technology can considerably reduce global freshwater withdrawals and thermal pollution." Thus, it stresses on the potential solutions	Accepted. Will be revised	Government of France	Ministère de la Transition écologique et solidaire	France
76631	36	24	36	30	Picturing the impacts on human health of nuclear power as being similar to those of renewable energies is highly questionable and would mean ignoring documented effects of radiation on human health, be it during regular operation or after a nuclear accident. To provide a few examples, a statistically significant increase in mortality from lung cancer was observed among former workers of the Wismut mine in Germany ; exposure to uranium mining waste among Navajo communities is significantly associated with an increased likelihood of hypertension and of developing one or more chronic diseases including hypertension, diabetes, and kidney disease ; a German study also highlighted a correlation between higher child cancer rates and the proximity of nuclear power plants. See : - L. Walsh, B. Grosche, M. Schnelzer, A. Tschense, M. Sogl, M. Kreuzer, 2015, A review of the results from the German Wismut uranium miners cohort Radiation Protection Dosimetry, Volume 164, Issue 1-2, April 2015, Pages 147–153, https://doi.org/10.1093/rpd/ncu281 - Lewis, J., Hoover, J. & MacKenzie, D. Mining and Environmental Health Disparities in Native American Communities. Curr Envir Health Rpt 4, 130–141 (2017). https://doi.org/10.1007/s40572-017-0140-5 - Kaatsch, PeterSpix, ClaudiaSchmiedel, SvenSchulze-Rath, RenateMergenthaler, AndreasBlettner, Maria, 2007, Epidemiologische Studie zu Kinderkrebs in der Umgebung von Kernkraftwerken : (KiKK-Studie), Deutsches Kinderkrebsregister, Mainz, urn:nbn:de:0221-20100317939 Health consequences of the Chernobyl accidents are also documented. Comparisons of morbidity/mortality in areas with low and high radioactive contamination reveal significant chromosomal abnormalities, marked increases in general morbidity, increased numbers of sick and weak newborns, and apparent accelerated ageing (Yablokov, 2009). Figures on excess death vary from several ten thousands (Cardis, 2005 ; TORCH, 2006) and 212,000 to 245,000 deaths in Europe and 19,000 in the rest of the world (Yablokov, 2009).	Taken into account. Only normal operation is included in LCA analysis. Reference Walsh et al 2015, analyses health impacts of uranium mining workers from 1946 - 1989. Much of the obeserved environmental and health impacts from uranium mining are from legacy operations rather than state-of-the-art facilities. See: https://www.jstor.org/stable/24385190. Please also see https://ec.europa.eu/info/sites/default/files/business_economy_euro/banking_and_finance/documents/210329-jrc-report-nuclear-energy-assessment_en.pdf	Charlotte MIJEON	Réseau "Sortir du nucléaire" (organiszation affiliated to the French Climate Action Network)	France
1003	36	27			endpoint	Accepted. Text revised.	Alok Dhaundiyal	Szent Istvan University	Hungary

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
4815	36	27	36	30	Opaque statement: delete or clarify. At least make it very clear that this concerns nuclear power in normal operating conditions – i.e. not taking into account major accidents. LCA studies have a reputation of being contingent on many important assumptions. Missing in this SOD of chapter 6 and in its reference list is the documented chapter 4 "Energy and Health" (Smith 2012) in the Global Energy Assessment.	Accepted. Text revised.	Aviel Verbruggen	University of Antwerp	Belgium
9177	36	27	36	30	Please reformulate or delete the phrase, the terms "end point" and "mid point" are not defined and may create confusion.	Accepted. Text revised.	Marin Constantin	RATEN ICN	Romania
20985	36	27	36	28	This is not clear. What is an "end point level" and in which direction ?	Accepted. Text revised.	Government of France	Ministère de la Transition écologique et solidaire	France
51109	36	27	36	28	"It commonly represents an end point level in LCA methods": the sentence should be clarified: what is the end-point and what is the direction?	Accepted. Text revised.	Eric PROUST	European Nuclear Society (ENS)	France
52187	36	27	36	27	What "It" refers to here?	Accepted. Text revised.	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
4817	36	31	36	31	"Nuclear power continues to suffer from limited public and political support". Comments: “continues to suffer” is a strange expression when scoping the history of nuclear power: no energy technology has ever received such prolific support and lavish financial resources as nuclear power. Research institutes, R&D programs, demonstration projects, advocacy, etc. were directly subsidized by public treasuries; the operations were paid by electricity consumers or tax payers, often supported by lenient regulators. Until today governments of the world finance the IAEA as promotional organisation for nuclear power. When a technology is not matured after 65 years of ample support, there are inherent failures to identify, and remedy if this is feasible or end the experiment when unfeasible to remedy.	Noted	Aviel Verbruggen	University of Antwerp	Belgium
8919	36	31	36	37	The references are old. Nowadays, there is a rise in the confidence in nuclear technologies. See for instance: https://www.irsn.fr/FR/IRSN/Publications/barometre/Documents/IRSN_Barometre_2020-analyse.pdf	Taken into account.	Jean-Guy DEVEZEAUX DE LAVERGNE	Université Paris-Dauphine & Société Française d'Energie Nucléaire	France
9179	36	31	36	31	Please reformulate "Nuclear power continues to suffer from limited public and political support (high confidence)". The assertion is valid for EU and some other countries.	Accepted. Text revised	Marin Constantin	RATEN ICN	Romania
14695	36	31	36	31	This statement should be balanced, as this is not the case for all regions/countries. For instance, countries such as Russia and China have clearly expressed their support to nuclear energy in their long-term energy strategies, with major construction plans.	Accepted. Text revised	Cécile Seguineaud	Indépendant consultant	France
18809	36	31	36	32	We suggest changing the text to: "Nuclear power continues to suffer from limited public and political support in some countries."	Accepted. Text revised	Tomáš Martanovič	Ministry of Industry and Trade	Czech Republic
20987	36	31	36	31	Is that a fact in all countries, such as Russia or China ?	Accepted. Text revised	Government of France	Ministère de la Transition écologique et solidaire	France
31471	36	31	36	31	"Nuclear suffer in some countries limited public and political support":	Accepted. Text revised	Carolina Ahnert	Universidad Politécnica de Madrid	Spain

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37135	36	31	36	37	The reported causalities from earlier nuclear accidents are substantially low compared to any other industries.	noted	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37137	36	31	36	37	Radiation fear among the public is due to lack of awareness, for example, the same person accepts	noted	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37139	36	31	36	37	ionised radiation for health care, medicine without fear. Life today is impossible without nuclear	noted	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37141	36	31	36	37	isotopes for their tremendous applications in industries and agriculture. Public education and awareness	noted	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37143	36	31	36	37	is required to promote nuclear energy. Several studies are available highlighting the health benefits of	noted	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37145	36	31	36	37	low dose radiations.	noted	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37147	36	31	36	37	The conventional approach for radiation protection is based on the ICRP's linear no threshold (LNT) model of radiation	noted	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37149	36	31	36	37	carcinogenesis, which implies that ionizing radiation is always harmful, no matter how small the dose is. There are a	noted	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37151	36	31	36	37	few case studies on the positive health effects of ionizing radiation. One of the examples can be obtained	noted	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37153	36	31	36	37	from the observed health effects of the serendipitous contamination of 1700 apartments in Taiwan, who	noted	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37155	36	31	36	37	were exposed to cobalt-60 (T1/2 = 5.3 y). Approximately 10,000 people occupied these buildings and	noted	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37157	36	31	36	37	received an average radiation dose of 0.4 Sv unknowingly, during a 9–20 year period. When the situation was	noted	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37159	36	31	36	37	realised, the health effects of the inhabitants were analysed against the long exposure of Co-60 radiation. It	noted	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37161	36	31	36	37	was found that the residents did not suffer a higher incidence of cancer mortality, as the LNT theory would	noted	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37163	36	31	36	37	predict. On the contrary, the incidence of cancer deaths in this population was greatly reduced to about 3 percent	noted	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37165	36	31	36	37	of the incidence of spontaneous cancer death in the general Taiwan public. In addition, the incidence of	noted	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India

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37167	36	31	36	37	congenital malformations was also reduced to about 7 per cent of the incidence in the general public.	noted	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37169	36	31	36	37	This experience indicates that chronic exposure of the whole body to low-dose-rate radiation, even accumulated to a	noted	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37171	36	31	36	37	high annual dose, may be beneficial tohuman health.	noted	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37173	36	31	36	37	Another example can be taken from the study of the coastal belt of Karunagappally, Kerala, India, which is	noted	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37175	36	31	36	37	known for high background radiation (HBR) from thorium-containing monazite sand. In certain locations of	noted	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37177	36	31	36	37	the coast, outer radiation levels are as high as 70 mGy/y and the median outdoor radiation levels are more	noted	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37179	36	31	36	37	than 4 m Gy/y. However, a cohort study of all 385,103 residents in Karunagapally revealed that there was no	noted	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37181	36	31	36	37	excess cancer risk from exposure to terrestrial gamma radiation. In summary, the dose criteria prescribed by	noted	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37183	36	31	36	37	ICRP needs to be reevaluated and that would eliminate the public fear of radiation due to a nuclear power	noted	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37185	36	31	36	37	plant. In future, more studies mucst be conducted to establish the beneficial effects of low level radiation	noted	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37187	36	31	36	37	and that will eliminate the fear in public.	noted	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37189	36	31	36	37	(Ref: W.L. Chen, Y.C. Luan, M.C. Shieh, S.T. Chen, H.T. Kung, K.L. Soong, Y.C. Yeh, T.S. Chou, S.H. Mong, J.T.	noted	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37191	36	31	36	37	Wu, C.P. Sun, W.P. Deng, M.F. Wu, M.L. Shen, Effects of cobalt-60 exposure on health of Taiwan residents	noted	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37193	36	31	36	37	suggest new approach needed in radiation protection, in: Abstr. Pacific Basin Nucl. Conf., 2004.	noted	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37195	36	31	36	37	https://doi.org/10.2203/dose-response.06-105.chen.	noted	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37197	36	31	36	37	R.R.K. Nair, B. Rajan, S. Akiba, P. Jayalekshmi, M.K. Nair, P. Gangadharan, T. Koga, H. Morishima, S. Nakamura,	noted	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
37199	36	31	36	37	T. Sugahara, Background radiation and cancer incidence in Kerala, India-Karunagappally cohort study, Health	noted	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37201	36	31	36	37	Phys. (2009). https://doi.org/10.1097/01.HP.0000327646.54923.11.)	noted	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37203	36	31	36	37	Another important point : Life of Nuclear Power plant is 60 years, compared to solar PV which is hardly 20 years	noted	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37205	36	31	36	37	Also the capacity factor is more than 85 % today compared to 20 % in solar PV.	noted	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37207	36	31	36	37	The costs associated with them need to be figured in the energy choice.	noted	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37685	36	31	36	31	There is high government support in India and many other countries. The comment on political support is not universally true.	Accepted. Text revised	Ravi B Grover	Homi Bhabha National Institute	India
51111	36	31	36	31	"Nuclear power continues to suffer from limited public and political support (high confidence)": this sentence is misleading because it is too general. Political support (if not also public support) appears quite significant in countries like China, Russia, India, the USA (under the Trump administration) the UK, France, Canada, Belarus, UAE, Polant, Slovakia, Hungaria, Romania, Turkey, Bulgaria, ... to name a few). "political support" should be deleted.	Accepted. Text revised	Eric PROUST	European Nuclear Society (ENS)	France
64411	36	31	36	44	It would be useful to the reader to have a graphic that summarizes public and political support for each mitigation option and associated factors. This section does an excellent job of summarizing these issues for nuclear energy but would make it easier to compare with other technologies if there was a single reference graphic. I see this is handled in table 6.9, but the table is too dense with information to be useful to a reader.	Take into account. Very relevant but unfortunately we do not have space to accommodate any figure in this section	Curt Bjurlin	Stantec Consulting	United States of America
74197	36	31	36	31	This line should be struck as it is fact dependent on the country and location. It should not be identified as high confidence. The studies used to support these assertions are dated and do not reflect recent data. They are also biased by the manner in which the quesitons are asked in the underlying surveys.	Accepted. Text revised	Jeffrey Merrifield	Pillsbury Law Firm	United States of America
78615	36	31	36	37	people also reject nuclear due to the massive profliferation risk, as documented by North Korea and Iran - less nuclear power plants in the world correlate with a reduces risk of proliferation	Noted	Christian Breyer	LUT University	Finland
84317	36	33	36	33	Insert civil in 'The major civil nuclear accidents…'	Taken into account. The text is about civil nuclear.	Vincent MAZAURIC	Schneider Electric	France
4819	36	36	36	36	“Public remains concerned about the safety risks of nuclear power plants and radioactive materials.” For sake of completeness, it should be mentioned that global insurance companies and top re-insurers are clearly concerned; by considering the enormous risks related to the operation of nuclear plants, they would have to ask premiums of several Euros/kWh!. Hence, there are no full indemnity insurance contracts around. Scientists are also concerned (e.g., Gillinsky, 2020).	Taken into account. It is about public acceptace and perception.	Aviel Verbruggen	University of Antwerp	Belgium
63165	36	36	36	37	In many countries, such as Japan, public concern is linked to risk perceptions and the level of trust in nuclear safety regulations, nuclear waste disposal policies, regulators, and policymakers. (Sklarew, J. 2018. “Power Fluctuations: How Japan’s Nuclear Infrastructure Priorities Influence Electric Utilities’ Clout.” Energy Research and Social Science, Volume 41. July: 158-167.)	Noted	Jennifer Sklarew	George Mason University	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
80553	36	37	36	37	It might be worth appending to this paragraph that the public acceptance to nuclear power has suffered also due to recent serious corruption scandals e.g. in the USA and South Korea. This needs to be addressed for nuclear's public acceptance to raise. A possible sentence might be: "Public trust in nuclear energy has been further eroded due to serious corruption in relation to nuclear energy, most recently discovered in South Korea (2019) and the United States (2020) (https://www.technologyreview.com/2019/04/22/136020/how-greed-and-corruption-blew-up-south-koreas-nuclear-industry/, https://www.nytimes.com/2020/08/02/opinion/utility-corruption-energy.html, https://www.worldnuclearreport.org/IMG/pdf/wnisr2020-v2_hr.pdf).	Taken into account. This is shortly covered by the text with a a reference to de Groot and Steg, 2011.	Moritz Riede	University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
4821	36	38	36	38	"At the same time, nuclear energy is seen in some quarters as a reliable energy source, beneficial for the economy and helpful in climate change mitigation." Because of the political content of this statement, the "some quarters" should be specified. It is remarkable that the knowledgeable and responsible agents in the power sector, i.e., private electric power companies, almost unisono reject to invest in new nuclear power - even when lavish public subsidies are offered.	Rejected. No need to state countries. Private sector has its own logic, profit logic	Aviel Verbruggen	University of Antwerp	Belgium
9181	36	38	36	39	Please reformulate "Nuclear energy is seen in some quarters as a reliable energy source, beneficial for the economy and helpful in climate change mitigation" in a less subjective. For example "the nuclear energy benefits consists of the reliablility, affordability of prices, climate change mitigation …but not always acknowledged."	Taken into account. It is about public perceptions and support.	Marin Constantin	RATEN ICN	Romania
9519	36	38	36	44	Two studies on nuclear power that are not cited in this section show that sense of place/place attachment is relevant for understanding both public attitudes and community responses to nuclear energy. First, Venables et al. (2012 - http://dx.doi.org/10.1016/j.jenvp.2012.06.003) showed that local community acceptance of new plants in the same location as old ones in the UK stemmed from how the existing plant had become a symbolic part of the landscape. Second, Wang et al (2020 - https://doi.org/10.1016/j.enpol.2020.111410) showed that the effect of place attachment on public support for new nuclear power plants in China is mediated by risk perceptions of local cost and benefit.	Accepted. Thank you for the references.	Patrick Devine-Wright	University of Exeter	United Kingdom (of Great Britain and Northern Ireland)
17177	36	38	36	39	The sentence does not present the advantages of nuclear power in a factual objective way. Rephrase: "The benefits of nuclear energy, as to be a reliable energy source and helpful in climate change mitigation and in some caseseven be seen as beneficial for the economy, are not always acknowledged."	Taken into account. It is about public perceptions and support.	Government of Poland	Ministry of Environment, Department of Air Protection and Climate	Poland
20989	36	38	36	39	The sentence "nuclear energy is seen in some quarters as a reliable energy source, beneficial for the economy and helpful in climate change mitigation" should be amended as follows to be factual and not subjective: "The benefits of nuclear energy, as to be a reliable energy source and helpful in climate change mitigation and in some caseseven be seen as beneficial for the economy, are not always acknowledged."	Taken into account. It is about public perceptions.	Government of France	Ministère de la Transition écologique et solidaire	France
31473	36	38	36	39	"Nuclear energy is a reliable energy source, beneficial for the economy and helpful in climate change mitigation":	Noted	Carolina Ahnert	Universidad Politécnica de Madrid	Spain
45455	36	38	36	40	Nuclear power plants contribution to climate change mitigation is not only carbon-free electricity, but also carbon-free district heat. They can be coupled with the district heating systems, providing heating with no greenhouse gases emissions. It is a mature technology, using currently existing light water reactors, providing heat in quite a few locations. Please see: https://doi.org/10.1016/j.pnucene.2020.103518	Taken into account. It is about public perceptions and support.	Maciej Lipka	National Centre for Nuclear Research	Poland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
51113	36	38	36	39	"Nuclear energy is seen in some quarters as a reliable energy source, beneficial for the economy and helpful in climate change mitigation": this sentence is subjective and should be rephrased to make it factual. For instance: "The benefits of nuclear energy -its reliability, its low GHG emissions helpfull for climate change mitigation and its benefits to the economy-, are not always acknowledged."	Taken into account. It is about public perceptions and support.	Eric PROUST	European Nuclear Society (ENS)	France
84319	36	38	36	38	Give the meaning of 'reliable': contributing to stability of the grid operation, the adequacy between supply and demand, etc.?	Taken into account. It is about public perceptions and support.	Vincent MAZAURIC	Schneider Electric	France
9183	36	39	36	40	Please delete as controversial "People who strongly endorse self-interest values are more likely to perceive such benefits of nuclear energy (Groot et al. 2013)."	Accepted. Text removed	Marin Constantin	RATEN ICN	Romania
17179	36	39	36	40	The sentence "People who strongly endorse self-interest values are more likely to perceive such benefits of nuclear energy (Groot et al. 2013)." could be controversial/misleading, and not universal. Moreover, it does not seem to be really of relevance (out of topic for this report) and is not studied in depth for every mitigation options and therefore should be deleted.	Accepted. Text removed	Government of Poland	Ministry of Environment, Department of Air Protection and Climate	Poland
17361	36	39	36	40	"People who strongly endorse self-interest values are more likely to perceive such benefits of nuclear energy (Groot et al. 2013)" I suggest to remove this sentence. I did not see this type of analysis being done for other energy sources so this aspect is not comparable among the variable energy sources. Even if it is true that selfish people support nuclear and generous people support solar/wind (I personally doubt about that): is that the reason to exclude nuclear from the battle against climate changes?	Accepted. Text removed	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
19649	36	39	36	40	Statement "People who strongly endorse self-interest values are more likely to perceive such benefits of nuclear energy (Groot et al. 2013)." seems to be controversial and higly misleading. Moreover, it does not seem to be relevant here (out of topic for this report) and is not studied in depth for every mitigation options and therefore should be deleted.	Accepted. Text removed	Government of Slovakia	State Advisor, Climate Change Policy Department Ministry of the Environment	Slovakia
20991	36	39	36	40	The sentence "People who strongly endorse self-interest values are more likely to perceive such benefits of nuclear energy (Groot et al. 2013)." could be controversial/misleading, it does not seem to be really of relevance (out of topic for this report) and is not studied in depth for every mitigation options and therefore should be deleted.	Accepted. Text removed	Government of France	Ministère de la Transition écologique et solidaire	France
31475	36	39	36	40	"People who strongly endorse self-interest values are more likely to perceive such benefits of nuclear energy (Groot et al. 2013).": this sentence is not appropriate in this type of document	Accepted. Text removed	Carolina Ahnert	Universidad Politécnica de Madrid	Spain
51115	36	39	36	40	"People who strongly endorse self-interest values are more likely to perceive such benefits of nuclear energy (Groot et al. 2013).": this sentence sould be deleted as it may be misleading or controversial, it is of little relevance for this report, and this sociological aspect is not dealt with for other energy sources	Accepted. Text removed	Eric PROUST	European Nuclear Society (ENS)	France
52189	36	39	36	39	What "self-interest values" means; this term is also used elsewhere in the text.	Accepted. Text removed	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
64243	36	42	36	48	OK – true statement - Public support also increases when trust in managing bodies is higher It is worth mentioning in this context the dedicated European Technology and Innovation Platforms (ETIPs) which are aimed to support the strengthening of confidence (both public and regulatory) in the safety and implementation of nuclear fission technologies: (1) the “Sustainable Nuclear Energy Technology Platform” (SNETP) which was established in September 2007 as a R&D&I platform to support and promote the safe, reliable and efficient operation of Generation II, II and IV civil nuclear systems. Since May 2019, SNETP has been operating as an international non-profit association (INPA) under the Belgian law pursuing a networking and scientific goals. The international membership base of the platform includes industrial actors, research and development organisations, academia, technical and safety organisations, SMEs as well as non-governmental bodies - https://snetp.eu/the-snetp-association/ (2) the above-mentioned ETIP dedicated to the “Implementation of Geological Disposal of Radioactive Waste” (IGD-TP), created in 2010, which aims to foster, promote and accelerate the implementation of geological disposal. (3) The Nuclear Generation II&III Alliance (NUGENIA) which is part of SNETP - https://snetp.eu/nugenia/	Noted	Georges VAN GOETHEM	Royal Academy of Overseas Sciences (ARSOM - KAOW)	Belgium
15539	36	45	36	45	The stated capital expenditure figure refers to two blocks nuclear power plant with a capacity of 2000 MW (e) and is estimated. It is better to use an estimate of capital investment per kW of installed capacity, for example, overnight costs ranged from $2021/kWe in South Korea to $6215/kWe in Hungary. - https://www.world-nuclear.org/information-library/economic-aspects/economics-of-nuclear-power.aspx. The most objective estimate of the economy of energy systems is the normalized cost of energy (LCOE), which for nuclear power is estimated at 83 percent per MWh, and, for example, solar ground PV - 132 U.S. dollars per MWh. (Nuclear Power and Sustainable Development, IAEA, Vienna 2016., p. 36)	Rejected. This is to show that individual investments can be of a very high size and need stable financial framework. Economic parameters (e.g. LCOE) are covered earlier.	Vladimir Kucinov	National Research Nuclear University "MEPHI" (Moslow Enginiring Physical Institute)	Russian Federation
31477	36	45	36	45	Include average project cost (not the maximum)	Rejected. This is to show that individual investments can be of a very high size and need stable financial framework. Economic parameters (e.g. LCOE) are covered earlier.	Carolina Ahnert	Universidad Politécnica de Madrid	Spain
51117	36	45	36	45	"individual projects can exceed USD 10 billion": mean/average values, not extreme values, should be given, just like for the other energy sources	Rejected. This is to show that individual investments can be of a very high size and need stable financial framework. Economic parameters (e.g. LCOE) are covered earlier.	Eric PROUST	European Nuclear Society (ENS)	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
78617	36	45	36	47	the reason is not only the high investment cost, as in several industries private companies go for larger single investments, such as oil & gas majors - the true reason that state owned companies are the 90% investors is that the entire business does not generate profit - it's simply not economic, there's no business case. This simple fact shall be clearly pointed out. See the extremely high cost, as detailed here WEO 2020 of the IEA see Tables B.2a/b, the Lazard reports (https://www.lazard.com/media/451419/lazards-levelized-cost-of-energy-version-140.pdf), and scientific literature, such as Ram et al. (https://www.sciencedirect.com/science/article/pii/S0959652618321486) - all this leads to phasing out private companies from that market so that they can avoid bankrupcy.	Rejected. This is to show that individual investments can be of a very high size and need stable financial framework. Economic parameters (e.g. LCOE) are covered earlier.	Christian Breyer	LUT University	Finland
4823	36	46	36	47	The information is factually wrong, because 41 of 50 units under construction in the world are either built in nuclear weapons states or build by nuclear weapons states controlled companies in other countries. The remaining are: 7 by South Korea's state controlled KEPCO, one by state controlled CNEA in Argentina. There is one privately owned utility building (more or less) a reactor in Japan. So 98% is a more appropriate % rather than "nearly 90%".	Noted	Aviel Verbruggen	University of Antwerp	Belgium
77235	36	46	36	47	The fact that "nearly 90% of nuclear power plants under construction are run by state-owned companies" is not due to the cost, but to the region where such projects are running. Many new projects are in China, in fact, where utilities are all state-owned. Since this point adds nothing, it is suggested to remove it.	Rejected. Goverments assume most of the risks and costs of such projects. It is difficult to assure private capital for nuclear in more liberalised markets	Giacomo Grasso	ENEA	Italy
1565	37	1	37	4	Subsidisation: To provide a balanced narrative, it should also be pointed out in the text here that nuclear has also benefitted and is continuing to benefit from substantial state subsidies and provide an outline of these. Reference should be made to nuclear dominating govermental energy R&D expenditure over the last 45 years (https://www.world-nuclear.org/information-library/economic-aspects/energy-subsidies.aspx), to direct subsidisation of recent nuclear plant cost over-runs (Olkiluoto, Flamanville, Vogtle 3 & 4 and VC Summer 2 & 3) and to subsidisation of waste disposal costs and insurance, through caps on liability for nuclear power stations. A succint summary is given in the following reference: https://www.parliament.vic.gov.au/images/stories/committees/SCEP/Inquiry_into_Nuclear_Prohibition_Inquiry_/Transcripts/11_September_2020/20201022_QoN_vic_nuclear_prohibition_inquiry_shac.pdf.	Taken into account. Nuclear subsidies are not mentioned in the text. The text does not discuss R&D expeditures for any techologies.	Martin Green	UNSW Sydney	Australia
2649	37	1	37	14	This paragraph fails to mention that there are also out-of-market payments in favour of nuclear power generation. For example, von Hirschhausen et al. (2015) argue that the provisions set up by German nuclear operators for dismantling and final disposal are 12 to 32 billion Euros lower than estimated costs. Von Hirschhausen et al. (2015): German nuclear phase-out enters the next stage: Electricity supply remains secure - Major challenges and high costs for dismantling and final waste disposal, DIW, http://hdl.handle.net/10419/110639	Taken into account. Text does not talk about dismantling and decommissioning.	Jan Wohland	ETH Zurich	Switzerland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
4825	37	1	37	4	Feed-in-tariffs and feed-in premiums have been applied during about two decades in some countries in the EU as innovation pull instrument for Renewable power technologies. In 2014, the EU commissioner changed the state aid guidelines limiting the role of these instruments to negligible for RE (Verbruggen et al., 2015). Since then, most EU countries as well as China do no longer support the main low-carbon power supply technologies wind and PV because they crossed the innovation “valley of death” to become the most competitive power supply options without subsidies and without compensation for their low-carbon and low-environmental impact (IRENA 2019c, 2020d). In 2014 the same commissioner allowed the UK to support Hinkley Point C with a generous 35 long FIT type support. Other nuclear projects under construction are also strongly subsidized, such as Akkuyu, Vogtle, etc.	Taken into account.Contract for Differences is not a FIT type of support, and it is available to all technologies in UK , not only nuclear.	Aviel Verbruggen	University of Antwerp	Belgium
64245	37	1	37	11	Indeed, feed-in-tariffs and feed-in premiums do not exist for nuclear power plants. As it has been said regarding p 6.5, new nuclear power will remain the dispatchable low-carbon technology with the lowest expected costs in 2025, according to the 2020 edition of the IEA Projected Costs of Generating Electricity. Source : IEA and NEA - Full report “Projected Costs of Generating Electricity 2020 — December 2020 » - https://www.iea.org/reports/projected-costs-of-generating-electricity-2020	Noted	Georges VAN GOETHEM	Royal Academy of Overseas Sciences (ARSOM - KAOW)	Belgium
64247	37	1	37	4	At the international level, there is a consensus that the maximum level of passive safety can be obtained through geological disposal. As it has been said regarding p 6.34, it is worth mentioning in this context the European Technology Platform for the Implementation of Geological Disposal of Radioactive Waste (IGD-TP), created in 2010, which aims to foster, promote and accelerate the implementation of geological disposal. The mission of the IGD-TP is to be a tool to support the strengthening of confidence (public and regulatory) in the safety and implementation of deep geological disposal solutions. https://igdtp.eu/activity/secigd-secretariat-of-the-implementing-geological-disposal-technology-platform/	Noted	Georges VAN GOETHEM	Royal Academy of Overseas Sciences (ARSOM - KAOW)	Belgium
72921	37	1	37	14	This paragraph at line 2 suggest that nuclear power "feels hard done" by policies. Maybe it should be added that it got the lion's share of public research money on energy during most of 50 years, and gets still about 25% of budgets in 2019 (IAE 2020) and even over two thirds in France (idem IAE 2020) https://www.iea.org/reports/energy-technology-rdd-budgets-2020 [also shown in box 16.4]	Taken into account. For nuclear as well as for other tecnologies subsidies (especially the R&D type) are not discussed in different sections.	Antoine BONDUELLE	EE-Consultant	France
78619	37	1	37	6	no single technology has received such high subsidies as nuclear power, thus claiming that support for renewables would distort the market is false. Nuclear has no relevant liability insurance which implies huge subsidies. Such enormous costs for society shall be mentioned. The UK has a FiT for nuclear which is about 120 €/MWh which is MUCH higher than what an entirely renewable energy system would cost - nuclear power is simply not competitive. For the case of UK with the new Hinkley nuclear plant and full substitute - with the same load profile - by renewables it had been shown that renewables cost less - see Child et al. (https://onlinelibrary.wiley.com/doi/abs/10.1002/we.2314)	Taken into account. For nuclear as well as for other technologies subsidies (especially the R&D type) are not discussed in different sections. Contract for Differences is not a FIT type of support, and it is available to all technologies in UK , not only nuclear.	Christian Breyer	LUT University	Finland
81917	37	1	37	6	It is unbalanced to state that support schemes for renewables distort prices for nuclear energy without mentioning the huge subsidies that all governments provide to nuclear energy whereever nuclear plants are built in the world (for research, construction, waste disposal and decommissioning).	Taken into account. For nuclear as well as for other technologies subsidies (especially the R&D type) are not discussed in different sections.	Anke Herold	Oeko-Institut e.V.	Germany

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1567	37	4	37	6	"distortion" has negative connotations whereas a more balanced assessment would see these price changes in a positive light, giving early market signals of the need for more storage or more flexible generation in future power grids. The IEA (WEO2020) reports that solar and wind dominated new global grid capacity additions over the 2016-2019 period with the IEA expecting even more complete domination in the future. With prices bid in recent unsubsidised PPAs for solar and wind also clearly undercutting all other options by large margins, it is clear these price signals are going to be amplified in the future. A mature assessment would deduce from the statement these are changes "which impact the revenues of existing nuclear plants", that nuclear is not a particularly attractive option for the future (given its stated inability to operate as profitably as expected even at this early stage of the grid transformation underway). These early price signals should be seen as valuable indicators for those contemplating further such investment rather than temporary distortions.	Rejected. Competitiveness of all technologies depends among others on market structure and organisation, it's not just about the cost of technologies.	Martin Green	UNSW Sydney	Australia
2733	37	4	37	7	I am not aware of evidence that out-of-market payments create negative prices. As far as I know, negative prices are a result of inflexible generators because it is cheaper for operators of such inflexible generators to sell at negative prices than to not sell at all.	Rejected. Out-of-market payments and priority treatment of some sources create price distortions.	Jan Wohland	ETH Zurich	Switzerland
4827	37	4	37	6	The "occasionally low or even negative prices" are an effect of redundancy in momentary power supply by inflexible power sources, being nuclear plants and renewable power from wind, light, water currents. They showcase the conflicts arising between nuclear power and renewable power from wind, PV and other natural currents (Haas et al. 2019). Subsidizing nuclear power is not advancing the deployment of wind, PV, and other RE: "these out-of-market payments create distortions" (for example the planned 35-year during £92.5/MWh indexed price guarantee for Hinkley Point C reactors under construction).	Rejected. Competitiveness of all technologies depends among others on market structure and organisation. Contract for Difference is a market mechanism and is availabale to all technologies (in UK).	Aviel Verbruggen	University of Antwerp	Belgium
71591	37	4	37	6	The subsidies are not the cause of the low prices - the low variable costs of renewables and nuclear are the reason for low electricity prices. Negative prices are caused by renewables not reacting to market signals (e.g under a FIT regime) in combination with an inflexible power system. This needs to be adapted. BuT: I is true that combining high shares of variable RES and nuclear in a power system is difficult as nuclear power plants are built for a relative stable operation and frequent cycling increases wear and tear (which in turn can have safety impacts or increases maintenance costs).	Noted	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
79625	37	4	37	7	The sentence which refers to électricity market distorsion has already been discussed. Furthermore, new NPP such as Hinkley point C in UK have a price guarantee per MWh. This later should be discussed here in view of the latest NPP transaction: Flamanville, Hinkley Point, Finnland, India, China. This will give antransparent idea of the financing of NPP.	Noted	Marc Daras	CentraleSupelecAlumni	France
80511	37	4	37	4	...but are supported indirectly by significant amounts of government subsidies e.g. in form of liability caps, and accurate data for nuclear subsidies is difficult to obtain (https://www.jstor.org/stable/j.ctt1ws7wjm.11, https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Apr/IRENA_Energy_subsidies_2020.pdf) .	Taken into account. Nuclear subsidies are not mentioned in the text. The text doesn not discuss R&D expeditures for any techologies.	Moritz Riede	University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
4829	37	6	37	11	The important aspect of nuclear waste is set aside with a few general comments on some procedural aspects of waste management. In the meantime, there is no operational final repository anywhere in the world for high level waste.	Taken into account. That's what is stated, but there's work towards it	Aviel Verbruggen	University of Antwerp	Belgium

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
55687	37	6	37	8	This is unsupported speculation. Many people think that viability depends mostly on cost. If this sentence is to remain, suggest changing ""will"" to ""may"", as follows: ""Nuclear power's long-term viability may hinge on demonstrating to the public and investors that there is a long-term solution to spent nuclear fuel.""	Accepted. Text revised.	Government of United States of America	U.S. Department of State	United States of America
76637	37	6	37	11	This part is working on the assumption that the main issue of nuclear waste management would be social acceptance and the capacity of building trust in management authorities, and that safety issues would already be fully addressed. However, the state of the art in Nordic countries cannot be considered as solving the global nuclear waste problem, disregarding country- and site-specific issues. In France, where the amount of nuclear waste bears no comparison with Sweden or Finland, the deep geological disposal facility project Cigéo faces sharp criticism from the Environmental Authority, major safety issues being insufficiently addressed. Beside, the nuclear waste issue is not to be solved all at once as soon as a nuclear waste deposit will be opened. Operations would then last for several decades (even for a century regarding the French disposal project), with persisting risks of nuclear waste transport accidents and accidents on site, be it in the surface facilities or underground. Concerning Cigéo, there would be no possibility to step in and retrieve waste in case of an underground accident. Similar problems already did happened in 2014 at the Waste Isolation Pilot Plant in New Mexico.	Noted	Charlotte MIJEON	Réseau "Sortir du nucléaire" (organiszation affiliated to the French Climate Action Network)	France
1007	37	7			the public	Accepted. Text revised	Alok Dhaundiyal	Szent Istvan University	Hungary
8921	37	7	37	8	This point can be controversial. Many countries (eg UK, Poland, Turkey, Saudi Arabia… and first of all China) have not stringent and urgent plans to dispose off High Level Radioactive waste. Thus, there is no eveident need to solve the question before building new NPPs. In France, the question is more complex: See Devezeaux et al. (2020) « Stockage des déchets radioactifs en profondeur : que décider ? quand décider ? » Jean-Guy Devezeaux de Lavergne, Linh Doan, Thierry Duquesnoy, Revue de l'Energie n°650, May-June 2020, ISSN 0303-240X, pp 27-48	Noted	Jean-Guy DEVEZEAUX DE LAVERGNE	Université Paris-Dauphine & Société Française d'Energie Nucléaire	France
17363	37	7	37	8	"… Nuclear power's long-term viability will hinge on demonstrating to public and investors that there is a long-term solution to spent nuclear fuel." Long-term solutions for radwaste are known. Controled storage for a couple of centuries is already implemented. Missing info, which should be added: volume (and mass) of nuclear waste is small: several hundred times lower than the mass of waste from solar energy for the same amount ef electricity produced. https://environmentalprogress.org/the-complete-case-for-nuclear	Noted	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
77237	37	8			Concerning spent nuclear fuel, it is proposed to add a sentence to the alternative solution to permanent disposal, which stands on recycling. E.g. "Spent fuel recycling is adopted in some countries using current reactors, presently allowing recovery of 95 to 97% of the fuel. The use of current reactors limits however the extent of recycling, so that several Generation-IV concepts are based on the principle of indefinite recycling of the spent fuel in the so called 'closed fuel cycle'. This option, whose viability has been already demonstrated, besides allowing an extension by a factor 50-100 of the available resources, would allow eliminating the need for permanent disposal in favor of temporary storages alike those currently operating worldwide." [Ref. OECD/NEA, 2006. "Advanced Nuclear Fuel Cycles and Radioactive Waste Management". Technical Report NEA-5990.]	Taken into account. Although relevant, can not be accommodated due to space limitations. Recycling makes more sense when there is a resource scarcity, which is not the case for uranium, thus recycling is a rather expensive option to engage in.	Giacomo Grasso	ENEA	Italy
20993	37	9	37	9	About "[...] Finland and Sweden" please consider the suggestion to add France, i.e. "Finland, Sweden and France"	Accepted. Text revised	Government of France	Ministère de la Transition écologique et solidaire	France
31479	37	9	37	9	France who is also workimg on a permanent disposal	Accepted. Text revised	Carolina Ahnert	Universidad Politécnica de Madrid	Spain
51119	37	9	37	9	"Finland and Sweden'': add France who is also steadily progressing towards a permanent geological repository (CIGEO Project)	Accepted. Text revised	Eric PROUST	European Nuclear Society (ENS)	France
1005	37	11			the proliferation	Accepted. Text revised	Alok Dhaundiyal	Szent Istvan University	Hungary
4831	37	11	37	14	The purely formal comments skip the essence of the problem, being: which proliferation occurred and was not precluded by the IAEA rulebooks; which institutional changes are helpful in curing the past and present problems. The framework is in place, but it gets vio-lated (e.g. NSG exception / US cooperation agreement with India) and thus has shown limited effect.	Taken into account. Beyond the scope of this doc.	Aviel Verbruggen	University of Antwerp	Belgium
18813	37	11	37	11	We suggest adding to the text: „Nuclear energy has potential to be a reliable energy source for hydrogen production.“	Accepted. The text is revised.	Tomáš Martanovič	Ministry of Industry and Trade	Czech Republic
43575	37	11	37	14	Please add some discussion of measures against terroristic threats related to non conventional nuclear weapons and dirty bombs, based on contraband nuclear fuel or waste.	Taken into account. Beyond the scope of this doc.	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy
48121	37	11	37	12	"The framework to address concerns about proliferation of nuclear weapons is in place since many decades…" Please clarify, like in a previous IPCC report, that the risk of weapons proliferation with nuclear energy proliferation is still high, and several countries have either tried or successfully developed weapons under the guise of civilian nuclear energy programs or nuclear energy research programs.	Taken into account. Proliferation issue is recognised, while enforcement goes beyond this doc	Mark Jacobson	Stanford University	United States of America
52191	37	11	37	14	Sentence comes out of the blue and the wording is unclear.	Noted	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
64249	37	11	37	14	Concerns about “proliferation of nuclear weapons” are addressed not only in IAEA guidelines but also in Euratom binding legislation. Indeed, the legal dimension of non-proliferation is devised at the EU level, assumed by Euratom and represented by the Euratom safeguards regime whereas the policy dimension belongs to the scope of the Union framework and is known as the Union’s non-proliferation. Source : “Consolidated version of the Treaty establishing the European Atomic Energy Community” OJ C 327, 26.10.2012, Chapter 7 – Safeguards - Article 77 to 85 - https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A12012A%2FTXT	Noted. The text covers it.	Georges VAN GOETHEM	Royal Academy of Overseas Sciences (ARSOM - KAOW)	Belgium
72923	37	11	37	14	The duration of the non proliferation regime is not a proof that it works well. It does what it can, but several recent nuclear weapons acquisitions show this does not suffice. Even if all comply with the rules it may not be enough, contrary to the sentence. Suggestion: mention "recent failures show this arrangement works with difficulty" or at the least "this regime could be improved"	Taken into account. There are always people who break the law - important is that issue has been recognised	Antoine BONDUELLE	EE-Consultant	France
76639	37	11	37	12	The existence of a framework to adress proliferation concern does not mean that the proliferation issue is actually under control, since it does not prevent countries from not respecting it (eg North Korea). In its January 2021 edition, the Bulletin of Atomic Scientists stated that "By our estimation, the potential for the world to stumble into nuclear war—an ever-present danger over the last 75 years—increased in 2020." (https://thebulletin.org/doomsday-clock/current-time/)	Taken into account. This is not non-priliferation analysis, issue is recognised	Charlotte MIJEON	Réseau "Sortir du nucléaire" (organiszation affiliated to the French Climate Action Network)	France
79627	37	11	37	12	The reference to proliferation of nuclear weapons seems improper here, or should it be linked with nuclear waste. It should be explicit.	Accepted. Text is revised to nuclear materials	Marc Daras	CentraleSupelecAlumni	France
80513	37	11	37	12	The framework is in place, e.g. the Non-proliferation Treaty, but it is not signed by everyone and adhered to by everyone. It would be good if this is mentioned here. Possible sentence “...is in place since many decades, but faces challenges with enforcement and several states that are not signatories (https://www.un.org/disarmament/wmd/nuclear/npt/)”	Taken into account. This is not non-priliferation analysis, issue is recognised	Moritz Riede	University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
1009	37	12			since many decades? For	Noted	Alok Dhaundiyal	Szent Istvan University	Hungary
20995	37	12	37	13	The non proliferation regime is a well established treaty, but the sentence suggests it works to satisfaction. The sentence could be completed like this: "Nuclear projects must comply with national and international norms and rules, such as IAEA guidelines, international treaties and conventions, and other industry standards (OECD IEA NEA 2020), however in some quarters those compliance should improve."	Taken into account. Issue is recognised and requires international aproach and action	Government of France	Ministère de la Transition écologique et solidaire	France
72889	37	12	37	13	The non proliferation regime is a well established treaty, but the sentence suggests it works to satisfaction. Maybe mention "recent failures show this works with difficulty" or at the least "could be improved"	Taken into account. Issue is recognised and requires international aproach and action	Antoine BONDUELLE	EE-Consultant	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
76641	37	12	37	14	This sentence is wishful thinking. The existence of international and national norms and rules does not mean that the different stakeholders abide by them. For example, a major fraud case was observed in 2016 at the French Le Creusot Forge plant, where the biggest steel components are forged, leading the Nuclear Safety Authority to hire anti-fraud specialists (http://www.french-nuclear-safety.fr/Information/News-releases/ASN-reviews-the-steps-taken-to-deal-with-counterfeit-suspect-and-fraudulent-items-CSFI). Violation of safety rules and of formal notices on French plants are still frequently reported by the Nuclear Safety Authority. Systematic falsifications of safety reports were also observed in South Korea (See Philip Andrews-Speed, South Korea's nuclear power industry: recovering from scandal, The Journal of World Energy Law & Business, Volume 13, Issue 1, March 2020, Pages 47–57, https://doi.org/10.1093/jwelb/jwaa010)	Taken into account. This is not non-priliferation analysis, issue is recognised	Charlotte MIJEON	Réseau "Sortir du nucléaire" (organiszation affiliated to the French Climate Action Network)	France
12201	37	14	37	14	In the nuclear energy section, we recommend adding another paragraph on the societal impact of nuclear energy and contribution to SDGs 1 and 8, regarding the impact on the job market. At the level of the EU, nuclear power ensures more than 50% of the total clean energy production with the nuclear sector securing 1,1 million jobs and an annual turnover of EUR 102 billion in GDP. By 2050, if new nuclear projects are initiated, it is expected that the nuclear industry would support more than 1.3 million jobs annually and generate EUR 576 billion per year in GDP. Also, I would add the contribution of nuclear energy to SDG 9 in terms of innovation and discuss about the application of non-electric uses of nuclear power for hydrogen production and seawater desalination.	Taken into account. Although relevant but not discussed in any technology sections of 6.4.2. Will be considered if space allows and if others also include it.	Lavinia Rizea	SN Nuclearelectrica SA	Romania
2651	37	15	40	12	Given the section title, I am surprised that DAC is not covered at all in this section. The section only talks about point source carbon capture and about storage.	Rejected. DAC is not covered in this section because only energy producing technologies are referenced here. DAC Is mentioned within a portfolio of net-zero emissions in section 6.6	Jan Wohland	ETH Zurich	Switzerland
8411	37	15	37	18	Technology for CCUS probably is quite mature, but the cost is prohibitive. It would not be realistic to consider CCUS as a solution in the near term (say 10 years) or even by 2050.	Rejected. Our conclusions here are based on our synthesis of the literature	Otto Poon	President, Hong Kong Academy of Engineering Sciences.	China
17365	37	15	37	15	CCUS is probably less relevant topic that can not be compared at the same level with major sources of energy. CCS (pg 38, line 15) is "technologically ready for full scale deployment". If this is true, than we cannot expect significant improvements in that field. However, it is also true that CCS today captures 3 orders of magnitude too small quantities of CO2 and is no economic. Does that mean that CCUS should be forgotten? If the topic stays here it presents a quiet support for further use of gas and coal...	Rejected. Our conclusions here are based on our synthesis of the literature	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
28509	37	15	40	11	This section does not include information on financial risks related with CCS, given the limitations flagged in the last 3-4 paragraphs. As shown here, for example: https://www.nasdaq.com/articles/asset-manager-blackrock-cuts-stake-in-occidental-petroleum-2021-02-05-0. There are also additional risks/liabilities related with the financial stability of oil companies. See https://www.ft.com/content/93b2c112-95f5-4d4b-8f48-761b698b7df5. I think these aspects, which are an important part of the assessment of CCS technologies, should be integrated in the narrative.	Taken into account. The financial risks (such as stranded assets) are covered in Section 6.7.3 and 6.7.4	Pierpaolo Cazzola	International Transport Forum	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
29427	37	15	37	15	Consider adding short introduction in chapter 6.4.2.5 in order to set the scene for CCS as possible climate mitigation technology in the transition to a low-carbon future: "Deployment of carbon capture storage (CCS) and/or utilization technology (CCU), either in the power sector or in hard-to abate industry e.g. cement and steel, will inevitably lead to increased cost /energy penalty compared to today's production and use. However, carbon capture, utilization and storage has an important role to play as an essential climate mitigation technology in the transition to a low-carbon future (IPCC 2018 An Intergovernmental Panel on Climate Change Special Report on the impacts of global warming), (IEAGHG 2019 CCS in Energy and Climate Scenarios)" Especially in four sectors, CCS has a critical role to play; Achieving deep decarbonisation in hard-to abate industry; enabling the production of low-carbon hydrogen at scale; providing low-carbon dispatchable power in combination with variable renewable energy (VRE); and delivering negative emissions through use of bioenergy and CCS. (Global CCS Institute 2020, THE VALUE OF CARBON CAPTURE AND STORAGE (CCS))	Accepted. A sentence has been added at the beginning	Government of Norway	Norwegian Environment Agency	Norway
43875	37	15	38	15	General comment about CCUS technology as a mitigaion tool: The concept of capturing carbon dioxide in the atmosphere and either store it in geologic formatins or use it to synthesize new products could be ideal at first thought but actually presents a major problem. Instead of mitigating climate change, it could become an instrument to further resort to fossil fuel consumption - especially the storage method which can be used for enhanced oil or gas recovery (EOR/EGR). This claim, of fossil fuel conumption, is not unfounded. Studies like Singh et al. (2012) [13] and Budinis et al. (2018) [14] significantly depletes natural resources like fossil fuels. Under the present context of embracing cleaner, more sustainable energy resources, supporting technologies that assures continuous reliance to fossil fuels should not be fully entertained as a promising option.	Refer to comment 17365	Vince Davidson Pacañot	University of the Philippines Diliman	Philippines
45887	37	15	40	11	Please reconsider whether the subsection "Carbon Dioxide Capture, Utilisation, and Storage" should be part of "Energy Sources and Energy Conversion" since there is no connection to energy generation or conversion.	Rejected. While CCUS itself does not produce energy, this decision has been made because it can mitigate emissions of several such technologies involving energy conversion.	Government of Germany	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety International Climate Policy	Germany
45889	37	15	48	19	In chapter 12 (p. 35) "potential CO2 leakage from deep geological reservoirs (BECCS)" is mentioned with reference to Chapter 6. But in Chapter 6 no explanations regarding leakage can be found. The non-permanence of geological storage could be a crucial point in the discussion of effectiveness of negative emission technologies and should be covered accordingly. Please elaborate on this issue, which is highly policy relevant.	Accepted. We have added a couple of sentence on the permanence of CCUS.	Government of Germany	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety International Climate Policy	Germany

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
47831	37	15	40	11	The paragraph misses an important distinction between fossil and biogenic carbon. The utilization of post-combustion fossil fuel CO2 is nothing but a recycling of fossil carbon (with respective energy expenses) while the utilization of biogenic carbon (e.g., from fermentation offgases) could results in significant net carbon reductions (drawdown potential). This life cycle aspect is not at all reflected in the CCU discussion in this section.	Noted. While this is an important discussion, we cannot include it because of space constraints.	Patrick Lamers	NREL	United States of America
47835	37	15	40	11	The life cycle assessment aspects of CCU/S technologies is not well and structurally covered in this section. Pls revise accordingly. The technology options should be distinguished by energy and water requirements, at minimum. Consider including these aspects in Table 6.2	Noted. While this is an important discussion, we cannot include it because of space constraints.	Patrick Lamers	NREL	United States of America
48123	37	15	40	11	Please discuss the problems with CCS as well. Namely, it is an opportunity cost and will not help in the solution to global warming. It always needs energyand equipment, so even using renewable energy to power it increases CO2, air pollution, and mining compared with using the same energy to replace fossil fuels Jacobson, M.Z., The health and climate impacts of carbon capture and direct air capture, Energy and Environmental Sciences, 12, 3567-3574, doi:10.1039/C9EE02709B, 2019. In addition, the additional cost of CCS is a regressive tax on poor households, which pay a higher share of their electricity bill on energy. CCS only increases the cost of fossil fuels and increases it proportionately more to poorer households.	Refer to comment 17365	Mark Jacobson	Stanford University	United States of America
48565	37	15	40	11	This subsection on CCUS is missing a few important points about CO2 utilization and has a slight inaccuracy. Particularly, this subsection does not mention catalyst performance when discussing main challenges of CO2 utilization, misrepresents the importance of carbon capture costs in overall CO2 utilization costs, and does not fully discuss policy options to promote CO2 utilization. The authors should cite the following reference that provides key information that is not included in this report: Bhardwaj, A., C. McCormick, and S.J. Friedmann, 2021: Opportunities and Limits of CO2 Recycling in a Circular Carbon Economy: Techno-economics, Critical Infrastructure Needs, and Policy Priorities, Center on Global Energy Policy. This reference provides a taxonomy and techno-economic analysis of 19 of the largest carbon abatement potential CO2 utilization pathways supplied by low-carbon inputs. This reference finds that the product selectivity and energy conversion efficiency of catalysts in chemical CO2 utilization processes is a main driver of total cost. This indicates that catalyst performance is a key challenge for many CO2 utilization pathways and suggests that policies focused on technological innovation, such as RD&D funding, would be effective at reducing CO2 utilization costs. Counter to what this chapter states on pg. 39 line 3, the reference finds that CO2 capture costs make up a small portion of the total cost of CO2 utilization production pathways. This reference also outlines a series of policy recommendations that could be mentioned in the paragraph that starts on pg. 40 line 5 of this chapter.	Noted. While this is an important discussion, we cannot include it because of space constraints.	Amar Bhardwaj	Stanford University	United States of America
69511	37	15	40	11	I would suggest disconnecting CCS and CCU throughout this entire discussion, as they do not at all offer the same potential to mitigate CO2 emissions. CCU, for example, is hardly compatible with net zero emissions.	Noted. While this is an important discussion, we cannot include it because of space constraints.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
71593	37	15	40	11	I think that two aspects of CCUS should be mentioned: the production of blue hydrogen and the inflexibility of CCS power plants (which might be a problem in combination with variable RES).	Taken into account. Blue hydrogen has been discussed later in section 6.6	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
74757	37	15	40	11	A clear picture of status of CCS on regional basis along with its projections over the years should be provided	Noted. While this is an important discussion, we cannot include it because of space constraints.	Debadutta Mohanty	CSIR - Central Institute of Mining and Fuel Research, Dhanbad	India
78621	37	15	40	11	the wording 'CCUS' is highly misleading and shall be split to 'CCU' and 'CCS'. Both concepts are highly different, and it is increasingly found in research that they are applied in a strongly opposed manner: CCU corresponds with Power-to-X and low-cost renewable electricity, while CCS is linked to fossil fuel use and the implicit assumption/input of high-cost renewable electricity. More can be found in Breyer et al. (https://www.cell.com/joule/fulltext/S2542-4351(19)30413-1) and Bruhn et al. (https://www.sciencedirect.com/science/article/pii/S1462901116300508)	Noted. While this is an important discussion, we cannot include it because of space constraints.	Christian Breyer	LUT University	Finland
47449	37	16	37	33	Despite the repetitive statements on power sector CCS as a low-carbon alternative, this section is extremely weak on specific content and does not provide ground for allowing CCS to be displayed as a viable alternative to renewables. Please revise here and in the relevant sections.	Refer to comment 17365	Government of Saint Lucia	Department of Sustainable Development - Ministry of Education, Innovation, Gender Relations and Sustainable Developement	Saint Lucia
61217	37	16	40	11	It is recommended to increase the evaluation of the impact of CCS and CCUS on the environment and ecosystems	Taken into account. Some of such discussion may be found in section 6.7.7.	Jianguo WU	chinese research academy of environmental sciences	China
76405	37	16	37	33	The discussion around CCUS presents and unrealistically optimistic picture. Recent example of large scale CCS projectys on the North West shelf of Australia have proven to be poor performers with very high technical risk. This goes to issues surrounding corrosion and energy use. Far more research into this technology needs to be carried out if this narrative is to be credible.	Refer to comment 17365	Robert Parker	Nuclear for Climate Australia	Australia
78161	37	16	37	33	This section is far from sufficient to provide ground for the repetitive statements on CCS, in particular as it is repeatedly referred to as a viable alternative to renewables in the power sector. If CCS is not a viable alternative (or only for very specific sectors given the limitations), this should be highlighted throughout the report. While it is discussed that obviously there are limits to CCS as well as feasibility barriers, this chapter needs to more clearly provide guidance on which sectors have more cost-effective options available, and which sectors will need to use CCS if net-zero emissions are to be achieved. The comparison of mitigation options across sectors should be improved, and implicit assumptions on the limitations of CCS need to be made more transparent.	Accepted. Improved discussion of comparative costs between mitigation options has been presented	Charlotte Plinke	Climate Analytics	Germany
69513	37	17	37	17	It's hard to understand how CCU is a "substitute" to geological storage. In most cases, if not all, the carbon captured and re-used will be combusted and released in the atmosphere.	Accepted. The sentence has been modified	Cédric PHILIBERT	Institut Français des Relations Internationales	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
29417	37	23	37	24	Please consider expanding on the solutions to the limitations of sink availability. CO2 can be transported by pipelines or ships, although costs are associated with transport of CO2, as is the case for many commodities (e.g. coal, gas, oil, ore, etc.). The global sink availability is not an issue in the forseeable future, and designating this as a "key limiting factor" seems to strong. Today it is important to establish functional playing fields and markets for CO2-storage and necessary infrastructure. The Longship-project in Norway will for example be able to recieve CO2 from most of northern Europe.	Accepted. We have added a sentence here on the possible alternatives e.g. international CCUS chains	Government of Norway	Norwegian Environment Agency	Norway
52193	37	24	37	24	Sentence starting on line 24 is redundant.	Rejected. Unclear comment	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
1361	37	25	37	26	Capacity in oil and gas reservoirs is limited, but so it is in saline aquifers. The question is if there is more or less capacity in O&G fields compared to saline aquifers, and the fact is that this is the case for some (important) regions in the world, such as the Gulf of Mexico or the Middle East (see Agartan et al., 2018 https://doi.org/10.1016/j.ijggc.2018.02.022 and Sun et al., 2020 https://doi.org/10.1016/j.gsf.2020.02.008). Besides, oil and gas reservoirs are likely the priority sites to be developed, because of the wealth of subsurface data and existing infrastructure (e.g. Alcalde et al., 2019 https://doi.org/10.1016/j.jclepro.2019.06.087).	Accepted. We have added greater clarity on this point and cited the suggested literature as well	Juan Alcalde	Geosciences Barcelona, CSIC	Spain
17847	37	26	37	27	The storage potential in the U.S. alone is much greater than 1000 Gt-CO2, so this nymber should be revised. The lower estimate for the US is >2000 GT-CO2. Same reference as cited in report (NETL 2015).	Noted. The number given here is an order-of-magnitude estimate.	Eve Tamme	Global CCS Institute	Belgium
45891	37	27	37	28	Please delete sentence. Comment: EOR and CCS need to be distinguished. In EOR no CO2-storage is intended.	Rejected. Our conclusions here are based on our synthesis of the literature	Government of Germany	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety International Climate Policy	Germany
1013	37	28			remove article	Accepted.	Alok Dhaundiyal	Szent Istvan University	Hungary
1357	37	28	37	30	The reference used to backup this sentence is not precise. Singh et al 2020 do not postulate why these are the desirable conditions for economic long-term storage, but use the values outlined in Chadwick et al. I suggest using the original reference, which is robust and well known worldwide. Chadwick RA, Arts R, Bernstone C, May F, Thibeau S andvZweigel P. Best practice for the storage of CO2 in saline aquifers. British Geological Survey Occasional Publication No.14, Keyworth, UK (2008).	Accepted. Additional reference added	Juan Alcalde	Geosciences Barcelona, CSIC	Spain

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
15099	37	28	37	30	"… the desirable conditions are depth of 800-2500 m…" It is suggested that the "800-2500 m" should be adjusted to 800-3000 M. The reasons are as follows: 3000m is also a feasible condition commonly used in many literatures, such as Literature (Fan et al., 2020; Li et al., 2005).Supporting literature: [1] Fan, J.-L., Shen, S., Wei, S.-J., Xu, M., Zhang, X., 2020. Near-term CO2 storage potential for coal-fired power plants in China: A county-level source-sink matching assessment. Applied Energy 279, 115878. [2] Li, X., Ohsumi, T., Koide, H., Akimoto, K., Kotsubo, H., 2005. Near-future perspective of CO2 aquifer storage in Japan: Site selection and capacity. Energy 30, 2360-2369.	Accepted.	Guoquan HU	National Climate Center of China Meteorological Adminstration	China
1015	37	29			the thickness	Rejected. Comment unclear	Alok Dhaundiyal	Szent Istvan University	Hungary
1017	37	30			mD?	Taken into account. mD here stands for milli Darcy i.e. unit of permeability	Alok Dhaundiyal	Szent Istvan University	Hungary
1359	37	31	37	33	The geological storage capacity is independent of the distance from the CO2 source and the sink, therefore the concept "viable capacity" used here is misleading. This paragraph describes the geological constraints of CO2 storage, and should not be mixed with economic considerations. I would remove this sentence or rephrased to: "In many cases, geological storage resource is not located close to the CO2 source, which might further increase the cost and thus reduce the viability of the CCS project".	Accepted.	Juan Alcalde	Geosciences Barcelona, CSIC	Spain
28375	37	31	37	33	The potential use of chemical carier e.g., LPG to transport LCO2, could mitigate this constraint. NorthernLights project in Norway is a pilot testing this and Global Carbon Capture Storage Initiative (GCCSI) out of Australia are also looking to address this	Noted. While this is an important discussion, we cannot include it because of space constraints.	Sanjay Kuttan	Singapore Maritime Institute	Singapore
5377	37	32	37	32	I would suggest to add a paragraph at this article, dealing with a fundamental point: To embark people in mitifation actions, it is essential that they receive an appropriate information, clear and objective, explaining why they should do this or that, what will be the actual benefit for them and for the collectivity, the potential inconvenience they may encounter, etc. the media hace a fundamental rôle doing this. Too often, the main media are more interested in publishing sensational information rather than academic information. The whole problem is complex and unfortunately, general public receive more information ditributed by commercials, lobbyist or activist than from scientific organisations.	Noted. While this is an important discussion, we cannot include it because of space constraints.	Michel SIMON	Retraité/ Pdt d'association	France
1027	37			40	effect on the geological storage (any negative effect)? Any govt. subsidy on CCUS?	Noted. While this is an important discussion, we cannot include it because of space constraints.	Alok Dhaundiyal	Szent Istvan University	Hungary
6043	37				Safeguards by design and sealed SMR designs also address proliferation concerns	Noted. While this is an important discussion, we cannot include it because of space constraints.	Adam Burak	University of Michigan	United States of America
2653	38	1	38	3	I am surprised by the accuracy of the numbers given in this Figure. What are the uncertainties here and should they not be discussed in the text?	Accepted. We have added a line in the caption indicating that these represent order-of-magnitude estimates	Jan Wohland	ETH Zurich	Switzerland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
15251	38	1	38	1	In Figure 6.13, the background colors of the maps of Taiwan Province and Chinese mainland are inconsistent. The East Section of China-India Border is wrongly drawn and the Dotted Line of South China Sea, Nanhai Zhudao, Diaoyu Dao and its affiliated islands of China are missing. It is suggested to delete the map and describe it in a tabular or graphical form. It is suggested to use a color block map if a map must be used, delete the national boundary lines, adjust the base color of Taiwan province to be consistent with Chinese mainland and mark the island points. As for the East Section of China-India Border, it is suggested to use a color block map or mark the line as claimed by the two sides in the disputed area.	Accepted	Government of China	China Meteorological Administration	China
86529	38	1	38	1	Figure 6.13 - Caution with political boundaries. figure shows china and taiwan as separate - risk that govts ask for this figure to be removed.	Accepted	raphael Slade	Imperial college	United Kingdom (of Great Britain and Northern Ireland)
45619	38	4	38	7	Implications of CO2 use need be studied in depth and from a multidisciplinary perspective. Such research may confirm that more opportunity for reaching negative CO2 emissions is available than currently assumed in integrated assessment models (IAMs) if one accounts for all possible CO2 use processes. IAMs scenarios are significantly limited to :i) agriculture, forestry and land use (AFOLU), and (2) BECCS (biomass energy in combination with CO2 capture and storage, or CCS)- Detz and Zwaan, 2019, Energy Policy, 133, 110938	Taken into account. Discussion of "negative emissions" or Carbon Dioxide Removal is presented in section 6.6.	Ana Machado	Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa	Portugal
47829	38	4	38	14	This paragraph needs to make it much more explicit that a CCU pathway to fuels is, strictly speaking, not a 'decarbonization' route. You would need to - at minimym - specify that such a decarbonization would need to displace the use of (underground) fossil fuels; and thus increase the carbon use efficiency of the existing fossil fuel system. Consider rephrasing esp. the statement made in the first sentence ('high confidence').	Accepted.	Patrick Lamers	NREL	United States of America
64885	38	4	38	5	How can one say that CCU is more viable when there is so little storage potenital? Again there is an implied perception that storage is not viable. This misperception must not be perpetuated	Accepted. Text modified	Katherine Romanak	The Univeristy of Texas at Austin	United States of America
69523	38	4	38	5	I wonder what is the basis for this statement. High confidence? Utilisation is much less likely to lead to decarbonisation, and very unlikely to be compatible with net zero emissions. Hepburn et alii (op.cit.) state that "Life-cycle analyses on some industrial CO2 utilization pathways suggest that the potential for net emission reductions is much larger than for net removals, which appears very modest."	Accepted. Text modified	Cédric PHILIBERT	Institut Français des Relations Internationales	France
78623	38	4	38	14	please provide the reference for the claim of 20 GtCO2 by mid-centry for CCU. One of the most comprehensive zero GHG emission studies with highly renewables and detailed CCU assumptions finds 6.1 GtCO2 raw material demand for CCU processes for sustainable fuels and chemicals. Mentioning such results and reference would increase the confidence for CCU. The study has been commissioned by the German Energy Agency, publicly available with ISBN number: https://www.powerfuels.org/fileadmin/powerfuels.org/Dokumente/Global_Alliance_Powerfuels_Study_Powerfuels_in_a_Renewable_Energy_World.pdf - the supply potential of sustainable or non-avoidable point sources is quantified to 20% and the other 80% is identifed as sourced by direct air capture (DACCU)	Accepted. The reference (Hepburn et al) has been provided	Christian Breyer	LUT University	Finland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
29419	38	5	38	7	The text states a CO2 utilisation potential of 1-2 Gt/yr that could increase to 20 Gt. Please clarify if this is the potential for CO2 as a feedstock or if it is the potential for reducing CO2 emission. The distinction is important because CO2 used as feedstock can in some cases lead to CO2 being emitted back to the atmosphere on a short time-scale.	Accepted. Text modified	Government of Norway	Norwegian Environment Agency	Norway
69515	38	6			If 20 Gt CO2 is used, how much will go in relatively durable goods (e.g. plastics) and how much will be rapidly combusted? The combustion of a large fraction of these 20 GT CO2 seems incompatible with net zero emissions.	Noted. While this is an important discussion, we cannot include it because of space constraints.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
45621	38	7	38	10	This feature is not a drawback of CCU it can be turned into an opportunity. As electricity is not easily stored, storage of excess electricity at a seasonal scale by CO2-based fuels can contribute to the introduction of renewable energy in the chemical production chain (Ampelli et al. 2015 Phil. Trans. R. Soc. A 373: 20140177).	Noted. While this is an important discussion, we cannot include it because of space constraints.	Ana Machado	Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa	Portugal
60453	38	7	38	8	Rephrase as follows: CCU involves using CO2 as a feedstock to synthesise products of economic value and as substitute to fossil feedstock. This means that even if CO2 is re-emitted after conversion, the process has involved net CO2 emission reductions and emission avoidance to produce e.g.chemicals, materials and synthetic fuels with much lower CO2 intensive budget compared to an equivalent fossil-based product." Find here a more comprehensive and adequate definition of CCU: Following the CCU concept, CO2 can be captured at point sources or directly from the atmosphere and subsequently converted into valuable products such as building materials, chemicals, synthetic fuels (e.g. Styring et al., 2011; von der Assen et al., 2013, SAPEA, 2018, Kätelhön et al., 2019). The duration of the CO2 storage into a product strongly varies from days to millenia according to the applications. However, in term of environmental assessment, CCU technologies should not be assessed only with respect to the amounts of CO2 that can be used nor to its storage duration, but rather it is essential to determine the life cycle of the CO2-based product generated (e.g. Bruhn et al., 2016, Zimmerman et al., 2018, Nocito and DiBenedetto al., 2020). If these products are assumed to be substitutes for fossil-based products and thus provide the same service (i.e. it would be used and disposed of according to the same patterns as conventional products), the focus of the life-cycle-analysis may lie in the cradle-to-gate phase (e.g. Kätelhön, et al., 2019). Two important points should however be highlighted (Arning et al., 2019, IEAGHG, 2019a, Zhu, 2019): 1)If CO2-based products can be produced with less environmental impact (including GHG emissions) than fossil-based ones, an environmental benefit can be asserted, independent of the storage time of CO2 in the products. 2)If CO2-based products are recycled i.e. if their end of life CO2 emissions are captured to generate new products, the duration of CO2 storage in a product is not anymore crucial to consider in the life cycle analysis.	Accepted.	Célia Sapart	Université Libre de Bruxelles / CO2 Value Europe	Belgium

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
76313	38	7	38	8	Suggestion to Rephrase: CCU involves using CO2 as a feedstock to synthesise products of economic value and as substitute to fossil feedstock. This means that even if CO2 is re-emitted after conversion, the process has involved net CO2 emission reductions and emission avoidance to produce e.g.chemicals, materials and synthetic fuels with much lower CO2 intensive budget compared to an equivalent fossil-based product." Two important points should however be highlighted (Arning et al., 2019, IEAGHG, 2019a, Zhu, 2019): 1)If CO2-based products can be produced with less environmental impact (including GHG emissions) than fossil-based ones, an environmental benefit can be asserted, independent of the storage time of CO2 in the products. 2)If CO2-based products are recycled i.e. if their end of life CO2 emissions are captured to generate new products, the duration of CO2 storage in a product is not anymore crucial to consider in the life cycle analysis. CO2 has already been used for decades with mature technologies in various industrial processes such as the food and beverage industry, urea production, water treatment and the production of fire retardants and coolants. But there are now many new CCU technologies at various stages of development from R&D to commercialization stage (Bushuyev et al., 2018). REFERENCES: •Bushuyev et al., 2018, Joule, 2(5), pp.825-832•SAPEA, 2018, Science Advice for Policy by EU Academies, Novel Carbon Capture and Utilisation Technologies-Research and Climate Aspects, Evidence Review Report, 2..•Kätelhön et al., 2019, PNAS, 116, 23, 11187-11194. •Von der Assen et al., 2013, Energy Environ. Sci. 6, 2721–2734.•Styring et al., 2011, Carbon Capture and Utilization in the Green Economy. Centre for Low Carbon Futures, York. •Zimmerman et al., 2018 , CO2 Chem Media and Publishing Ltd., •Bruhn et al., 2016, Environmental Science & Policy, 60, 38–43. •Nocito and Dibenedetto, 2020, Current Opinion in Green and Sustainable Chemistry, 21, 34–43.•Arning et al. 2019, Energy Policy, 125, 235–249.•IEAGHG, 2019a: Putting CO2 to Use – Creating value from emissions.	Refer to comment 76313	Deepak PANT	Flemish Institute for Technological Research (VITO)	Belgium
78807	38	7	38	8	The following statement could be completed to introduce the major value of CCU which is the use of CO2 as a substitute to fossil feedstock. "CCU involves using CO2 as a feedstock to synthesise products of economic value + and as a substitute to fossil resource extraction. Consequence of this substitution feedstock substutution is CO2 emission avoidance and the production of chemicals, materials and synthetic fuels with much lower CO2 intensive footprint compared to an equivalent fossil-based product." Once could add : "For sectors hard to decarbonise or defossilize like fuels for long distance aviation, CCU based products remain the unique solution as alternative to fossil kerosen" Before reading disadvantages of CCU et needs of energy, problems with CO2 purity, it would be great to read in this chapter the 3 figures of value from CCU (fossil substitution generating CO2 emission avoidance, defossilized energy and goods supplying (not the case with CCS), CO2 sequestration duration).	Refer to comment 76313	Sylvain Nizou	CEA	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
83697	38	7	38	8	Rephrase as follows: CCU involves using CO2 as a feedstock to synthesise products of economic value and as substitute to fossil feedstock. This means that even if CO2 is re-emitted after conversion, the process has involved net CO2 emission reductions and emission avoidance to produce e.g.chemicals, materials and synthetic fuels with much lower CO2 intensive budget compared to an equivalent fossil-based product." Find here a more comprehensive and adequate definition of CCU: Following the CCU concept, CO2 can be captured at point sources or directly from the atmosphere and subsequently converted into valuable products such as building materials, chemicals, synthetic fuels (e.g. Styring et al., 2011; von der Assen et al., 2013, SAPEA, 2018, Kätelhön et al., 2019). The duration of the CO2 storage into a product strongly varies from days to millenia according to the applications. However, in term of environmental assessment, CCU technologies should not be assessed only with respect to the amounts of CO2 that can be used nor to its storage duration, but rather it is essential to determine the life cycle of the CO2-based product generated (e.g. Bruhn et al., 2016, Zimmerman et al., 2018, Nocito and DiBenedetto al., 2020). If these products are assumed to be substitutes for fossil-based products and thus provide the same service (i.e. it would be used and disposed of according to the same patterns as conventional products), the focus of the life-cycle-analysis may lie in the cradle-to-gate phase (e.g. Kätelhön, et al., 2019). Two important points should however be highlighted (Arning et al., 2019, IEAGHG, 2019a, Zhu, 2019): 1)If CO2-based products can be produced with less environmental impact (including GHG emissions) than fossil-based ones, an environmental benefit can be asserted, independent of the storage time of CO2 in the products. 2)If CO2-based products are recycled i.e. if their end of life CO2 emissions are captured to generate new products, the duration of CO2 storage in a product is not anymore crucial to consider in the life cycle analysis.	Refer to comment 76313	Christian Breyer	LUT University	Finland
69517	38	8	38	10	About 40% of the methanol is currently used as an energy product, 60% as feedstocks. However, it's precisely because the highest potential for CCU exists in sector that delivers energy products, that CCU is hardly compatible with NZE.	Noted. While this is an important discussion, we cannot include it because of space constraints.	Cédric PHILIBERT	Institut Français des Relations Internationales	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
77999	38	8	38	12	Suggested Edit: Change these two sentences to: "Buliding materials made up the largest (approximately 30 GT) of four major categories of annual global materials extraction (Building materials, Biomass, Fossil energy carriers, Ores and industrial materials) by weight (approximately 70 GT) in 2009, and concrete makes up about two-thirds of all building materials (European Environmental Agency 2016) (Gagg 2014). Low carbon and carbon negative concrete and aggregate are currently being produced at commercially competitive prices by multiple firms (Fiekowsky, 2020). Carbon fiber replacements for steel and aluminum are also currently being produced. Potential building material CCU could reach 10 GT/Yr in 50 years (Eisenberger, 2020). Another important sector for CCU exists in sectors that deliver energy products … and methane (part of the approximately 10 GT in 2009, Fossil energy carrier sector). Both building materials and energy products represent endothermic reaction ... (Eisenberger 2020) (Hoppe et al. 2018) (Daggash et al. 2018). When carbon-rich fuel .... atmosphere. However, most carbon used in building materials can be, relative to human time scales, permanently sequestered. Because of ... (Wei et al. 2020). However, economically feasible ambient air DAC technologies that are more geographically flexible have been developed (ASUNow 2019) (Baiman 2021,2020)." Rationale: See (Baiman 2021,2020). References: ASUNow. 2019. Popular Science picks ASU professor's 'MechanicalTree' as a 2019 top technology. Dec. 5 I20 Baiman, Ron. 2021. In Support of a Renewable Energy and Materials Economy (REME): A Global Green New Deal (GGND) that Includes Arctic Sea-Ice Climate Triage and Carbon Cycle Climate Restoration. Submitted to the Review of Radical Political Economics. Accessed at: https://www.cpegonline.org/post/arctic-sea-ice-traige-carbon-cycle-restoration-and-a-renewable-energy-and-materials-economy	Noted. While this is an important discussion, we cannot include it because of space constraints.	Ron Baiman	Benedictine University	United States of America
78625	38	8	38	9	the statement is not clear. The sentence shall be differentiated for the source of CO2 and the demand for CO2 as raw material. For the case of the source, it shall be mentioned that one of the largest sources for sustainable CO2 may origin from direct air capture (as discussed in detail in Breyer et al. - https://www.cell.com/joule/fulltext/S2542-4351(19)30413-1). For the demand side it shall be mentioned that Fischer-Tropsch based jet fuel will be one of the largest demand sectors.	Taken into account. The use of DAC as a CO2 source has been discussed in section 6.6.	Christian Breyer	LUT University	Finland
45623	38	10	38	12	However, end of life CO2 emissions of CO2-based fuels do not jeopardize their benefits in terms of climate benefits. For instance, in the CCU system the intensive fossil resource consumption by the conventional formic acid process is displaced by the use of the CO2 captured, contributing to the double decarbonisation of the power system and chemical production. Aldaco et al., 2019, Science of the Total Environment, 663, 738-753.	Refer to comment 76313	Ana Machado	Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa	Portugal
45625	38	10	38	12	Another example is: both CO2-derived methane and methanol can provide climate benefits, but the use of low carbon energy for their production is critical. CO2 emissions can be reduced by 74% to 93% for methanol and 54% to 87% for e-methane as compared to conventional production routes (IEAGHG, 2019a: Putting CO2 to Use – Creating value from emissions, International Energy Agency).	Noted. While this is an important discussion, we cannot include it because of space constraints.	Ana Machado	Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa	Portugal

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
45627	38	10	38	12	Besides life-cycle analysis demonstrate that both point source and DAC to fuel pathways can provide climate benefit over conventional diesel fuel if a low carbon source of electricity is used (e.g. Daggash et al., 2018, Sustainable Energy Fuels, 2, 1153-1169, Concawe, 2019, A look into the role of e-fuels in the transport system in Europe (2030–2050) (literature review),; Liu et al., 2020, Sustainable Energy Fuels, 4, 3129-3142).	Refer to comment 78625	Ana Machado	Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa	Portugal
69519	38	12	38	12	Non sequitur: the limitation of CO2 utilisation avenue comes from the need to reduce emissions, much more than by energy availability.	Noted. While this is an important discussion, we cannot include it because of space constraints.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
70147	38	12			availability. This combination of high energy requirements and potential for net-positive emissions could even result in an "important co-benefit of increasing domestic oil production…"" (U.S. Department of Energy 2016). https://www.energy.gov/epsa/downloads/carbon-capture-utilization-and-storage-climate-change-economic-competitiveness-and	Noted. While this is an important discussion, we cannot include it because of space constraints.	Rayner Andersen	Department of Fisheries and Oceans	Canada
1019	38	13			article missing the presence , some region	Rejected. Comment unclear	Alok Dhaundiyal	Szent Istvan University	Hungary
70149	38	14			(Wei et al. 2020). In addition, Sgouridis et al. (2019) has shown that investment in "renewable technologies generally provide a better energetic return than CCS." Where energetic returns from CCUS projects range from 6.6:1 and 221.3:1, while the energetic returns on renewable energy investments range from 9:1 to 30:1 or above. They conclude that "Therefore, renewables plus [battery] storage provide a more energetically effective approach to climate mitigation than constructing CCS fossil-fuel power stations." As a result, the cost-effectiveness of investing in CCUS prior to high renewable energy penetration is questionable. https://www.nature.com/articles/s41560-019-0365-7	Noted. While this is an important discussion, we cannot include it because of space constraints.	Rayner Andersen	Department of Fisheries and Oceans	Canada
51121	38	15	40	11	Mention is made in Section 6.2.4.5 of the potential risk of limited public acceptance of CO2 storage in inhabited regions Damen, K., Faaij, A. & Turkenburg, W. Health, Safety and Environmental Risks of Underground Co2 Storage – Overview of Mechanisms and Current Knowledge. Climatic Change 74, 289–318 (2006). https://doi.org/10.1007/s10584-005-0425-9	Noted. We have already provided other references which synthesize recent literature for this point	Eric PROUST	European Nuclear Society (ENS)	France
64837	38	15	38	18	add reference Giannaris, S., Bruce, C., Jacobs, B., Srisang, W., & Janowczyk, D. (2020). Implementing a second generation CCS facility on a coal fired power station–results of a feasibility study to retrofit SaskPower's Shand power station with CCS. Greenhouse Gases: Science and Technology, 10(3), 506-518.	Accepted.	Katherine Romanak	The Univeristy of Texas at Austin	United States of America
10931	38	18	38	20	please insert the numeric value for the energy penalty of Boundary Dam and Petra Nova	Noted. While this is an important discussion, we cannot include it because of space constraints.	Dong-Woon NOH	Korea Energy Economics Institute	Republic of Korea
16355	38	18	38	20	please insert the numeric value for the energy penalty of Boundary Dam and Petra Nova	Refer to comment 10931	Government of Republic of Korea	Korea Meteorological Administration (KMA)	Republic of Korea
1021	38	19			a solvent, avoid space (MEA) n article , post-combustion	Accepted	Alok Dhaundiyal	Szent Istvan University	Hungary
1023	38	20			article missing (the commerical-scale)	Accepted	Alok Dhaundiyal	Szent Istvan University	Hungary
17903	38	20			Petra Nova has been mothballed	Accepted. Text modified	Robert Brecha	Climate Analytics	Germany
1025	38	21			check article	Accepted.	Alok Dhaundiyal	Szent Istvan University	Hungary

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
70141	38	21			(Mantripragada et al. 2019). However, Petra Nova was shut down on May 1st, 2020 with NRG citing low oil prices as the cause. Over its three years of operation, the plant missed its carbon capture goal by about 17%. In addition, there remains questions on if the Petra Nova plant was net-negative or net-positive CO2 emissions over its lifespan: “the total impact of the carbon capture system is actually an estimated 2% increase in CO2 emissions.” (ScottMadden 2018). https://www.scottmadden.com/insight/billion-dollar-petra-nova-coal-carbon-capture-project-financial-success-unclear-can-replicated/	Refer to comment 17903	Rayner Andersen	Department of Fisheries and Oceans	Canada
61979	38	25	38	25	Typo: change "Bhave et al. 2017; Yang et al. 2019)Another" to "Bhave et al. 2017; Yang et al. 2019). Another"	Accepted	Esa Vakkilainen	LUT University, Lappeenranta	Finland
17855	38	27	38	28	The term “net efficiencies” is ambiguous. “Efficiency” is sometimes used to describe the capture fraction (CO_2 captured as % of total CO_2). The term “net energy efficiency” would be clearer. According to the reference Scaccabarozzi et al. (2016) P.509 of Scaccabarozzi says “The comparison between the two cases employing 99.5% vs. 97% oxygen purity reported in [21] shows that the maximum cycle efficiency is achieved with the highest purity”.	Accepted.	Eve Tamme	Global CCS Institute	Belgium
17857	38	29	38	29	This depends on the utilisation case. Use in greenhouses is TRL 9 and happening now, same for EOR. Urea manufacturing (also TRL 9) already uses CO_2 recovered from other industrial processes (e.g. as byproduct of ammonia production). These show that in some cases CO2 utilisation has moved well beyond the lab and pilot phases. The technology development of CO2 utilisation is not uniform and varies widely between applications.	Accepted.	Eve Tamme	Global CCS Institute	Belgium
45629	38	29	38	29	This sentence does not reflect the actual situation. CCU technologies include some that are close to commercialization, others are at the pilot scale, and some are still in research phase. Thermochemical and bioelectrochemical are the most advanced technologies These pathways are the closest to commercialization and are ready to be upscaled in near-term (5-10 years) while other routes such as the direct electrochemical pathways are promising on the long-term but will take at least 10 years to overcome the current technical barriers (Diaz et al., 2018, Green Chem., 2018, 20, 620-626; Messias et al. Reaction Chem. &Eng. , 2019, 4, 1982-1990; Edwards et al. Applied Energy , 2019, 261, 114305; Bushuyev et al., 2018, Joule, 2(5), pp.825-832; Masel et al. Nature Nanotechnology, 2021, 16, 118-128). In Europe exist ca. 50 high Technology Readiness Level (TRL) projects on CO2 to fuel many of them will reach commercialisation in the near-term (before 2030). Examples of forecasted production of CO2-based fuel in near-term (within 5 years) are: - Norsk-efuel (DAC to jet-fuel)=> 100 Million ton of jet-fuel/year - Carbon Recycling International => 4000 tons of methanol/year - Jupiter 1000 (CO2 flue gas to CH4) : 25Nm3/h of methane - North CCUhub (CO2 to methanol)=> 44000 tons of methanol/year - Mo-Industrial e-fuel (CO2 to methanol)=> 80 000 tons of methanol/year - C2Fuel (CO2 to formic acid) => 2.4 Million tons of formic acid/year - Audi e-gas plant (CO2 to methane => 1000 tons of methane/year	Accepted	Ana Machado	Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa	Portugal
47833	38	29	38	29	There is a great deal of difference between lab and prototype/demonstration scale. Here these important development stages are meshed together and no technology distinctions (which ones are in which phases) provided. It would significantly strengthen the text to distinguish the stages per CCU technology options and applications (per sector).	Accepted.	Patrick Lamers	NREL	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
60455	38	29	39	2	This statement is erroneous and does not reflect the current state of peer-reviewed litterature. CO2 has already been used for decades with mature technologies in various industrial processes such as the food and beverage industry, urea production, water treatment and the production of fire retardants and coolants. But there are now many new CCU technologies at various stages of development from R&D to commercialization stage (e.g. about 60 large-scale projects at high Technology Readiness Level are currently ongoing in Europe and have reached or will reach commercialization in the near-term. Some examples are: North CCU Hub, Norsk e-fuel, STEELANOL, JUPITER 1000, INITIATE, C2Fuel, Carbon2Chem, CO2Fokus, COLUMBUS). Some examples of already commercialised CCU technologies: Carbon8Systems (UK), Climeworks (Switzerland), Carbon Upcycling (Canada), Covestro (Germany), Orbix (Be), Lanzatech (US), UR One (Canada), Carbon Recyclng International (Iceland). In term of technologies, recent advances in the CCU field offer untapped potential for the realization of CO2 conversion to fuels. Today, a large palet of technologies exist, some are close to commercialization, others are at the benchtop/pilot scale, and some have yet to be scientifically proven. Thermochemical and bioelectrochemical routes offer the most technically feasible near-term opportunities for CO2-based fuels upscaling, representing immediately deployable pathways to high-value and relatively high-volume products. These pathways are the closest to commercialization and are ready to be upscaled in near-term (5-10 years) while other routes such as the direct electrochemical pathways are promising on the long-term but will take several decades to overcome the current technical barriers (Diaz et al., 2018, Messias et al. 2019, Edwards et al., 2019, Bushuyev et al., 2020, Masel et al., 2021). Close to 50 high Technology Readiness Level (TRL) projects on CO2 to fuel exist in Europe and many of them will reach commercialisation in the near-term (before 2030). Please find a few examples below with the forecasted production of CO2-based fuel in near-term (within 5 years): -Norsk-efuel (DAC to jet-fuel)=> 100 Million ton of jet-fuel/year	Accepted.	Célia Sapart	Université Libre de Bruxelles / CO2 Value Europe	Belgium

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
76315	38	29	39	2	This statement is erroneous and does not reflect the current state of peer-reviewed litterature. CO2 has already been used for decades with mature technologies in various industrial processes such as the food and beverage industry, urea production, water treatment and the production of fire retardants and coolants. But there are now many new CCU technologies at various stages of development from R&D to commercialization stage (e.g. about 60 large-scale projects at high Technology Readiness Level are currently ongoing in Europe and have reached or will reach commercialization in the near-term. Some examples are: North CCU Hub, Norsk e-fuel, STEELANOL, JUPITER 1000, INITIATE, C2Fuel, Carbon2Chem, CO2Fokus, COLUMBUS). Some examples of already commercialised CCU technologies: Carbon8Systems (UK), Climeworks (Switzerland), Carbon Upcycling (Canada), Covestro (Germany), Orbix (Be), Lanzatech (US), UR One (Canada), Carbon Recyclng International (Iceland). In term of technologies, recent advances in the CCU field offer untapped potential for the realization of CO2 conversion to fuels. Today, a large palet of technologies exist, some are close to commercialization, others are at the benchtop/pilot scale, and some have yet to be scientifically proven. Thermochemical and bioelectrochemical routes offer the most technically feasible near-term opportunities for CO2-based fuels upscaling, representing immediately deployable pathways to high-value and relatively high-volume products. These pathways are the closest to commercialization and are ready to be upscaled in near-term (5-10 years) while other routes such as the direct electrochemical pathways are promising on the long-term but will take several decades to overcome the current technical barriers (Diaz et al., 2018, Messias et al. 2019, Edwards et al., 2019, Bushuyev et al., 2020, Masel et al., 2021). Close to 50 high Technology Readiness Level (TRL) projects on CO2 to fuel exist in Europe and many of them will reach commercialisation in the near-term (before 2030). Please find a few examples below with the forecasted production of CO2-based fuel in near-term (within 5 years): -Norsk-efuel (DAC to jet-fuel)=> 100 Million ton of jet-fuel/year	Accepted.	Deepak PANT	Flemish Institute for Technological Research (VITO)	Belgium

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
78809	38	29	38	29	"The technological development for CO2 utilisation is still in the laboratory, prototype, and pilot phases". This is erroneous! Some examples are: North CCU Hub, Norsk e-fuel, STEELANOL, JUPITER 1000, INITIATE, C2Fuel, Carbon2Chem, CO2Fokus, COLUMBUS).Some examples of already commercialised CCU technologies: Carbon8Systems (UK), Climeworks (Switzerland), Carbon Upcycling (Canada), Covestro (Germany), Orbix (Be), Lanzatech (US), UR One (Canada), Carbon Recyclng International (Iceland). In term of technologies, recent advances in the CCU field offer untapped potential for the realization of CO2 conversion to fuels. Today, a large palet of technologies exist, some are close to commercialization, others are at the benchtop/pilot scale, and some have yet to be scientifically proven. Thermochemical and bioelectrochemical routes offer the most technically feasible near-term opportunities for CO2-based fuels upscaling, representing immediately deployable pathways to high-value and relatively high-volume products. These pathways are the closest to commercialization and are ready to be upscaled in near-term (5-10 years) while other routes such as the direct electrochemical pathways are promising on the long-term but will take several decades to overcome the current technical barriers (Diaz et al., 2018, Messias et al. 2019, Edwards et al., 2019, Bushuyev et al., 2020, Masel et al., 2021). Close to 50 high Technology Readiness Level (TRL) projects on CO2 to fuel exist in Europe and many of them will reach commercialisation in the near-term (before 2030). Please find a few examples below with the forecasted production of CO2-based fuel in near-term (within 5 years): - Norsk-efuel (DAC to jet-fuel)=> 100 Million ton of jet-fuel/year - Carbon Recycling International => 4000 tons of methanol/year - Jupiter 1000 (CO2 flue gas to CH4) : 25Nm3/h of methane - North CCUhub (CO2 to methanol)=> 44000 tons of methanol/year REFERENCES: • Masel et al. Nature Nanotechnology, 2021, 16, 118-128. • Messias et al. Reaction Chem. &Eng. , 2019, 4, 1982-1990.• Bushuyev et al., 2018,	Accepted.	Sylvain Nizou	CEA	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
83699	38	29	39	2	This statement is erroneous and does not reflect the current state of peer-reviewed litterature. CO2 has already been used for decades with mature technologies in various industrial processes such as the food and beverage industry, urea production, water treatment and the production of fire retardants and coolants. But there are now many new CCU technologies at various stages of development from R&D to commercialization stage (e.g. about 60 large-scale projects at high Technology Readiness Level are currently ongoing in Europe and have reached or will reach commercialization in the near-term. Some examples are: North CCU Hub, Norsk e-fuel, STEELANOL, JUPITER 1000, INITIATE, C2Fuel, Carbon2Chem, CO2Fokus, COLUMBUS). Some examples of already commercialised CCU technologies: Carbon8Systems (UK), Climeworks (Switzerland), Carbon Upcycling (Canada), Covestro (Germany), Orbix (Be), Lanzatech (US), UR One (Canada), Carbon Recyclng International (Iceland). In term of technologies, recent advances in the CCU field offer untapped potential for the realization of CO2 conversion to fuels. Today, a large palet of technologies exist, some are close to commercialization, others are at the benchtop/pilot scale, and some have yet to be scientifically proven. Thermochemical and bioelectrochemical routes offer the most technically feasible near-term opportunities for CO2-based fuels upscaling, representing immediately deployable pathways to high-value and relatively high-volume products. These pathways are the closest to commercialization and are ready to be upscaled in near-term (5-10 years) while other routes such as the direct electrochemical pathways are promising on the long-term but will take several decades to overcome the current technical barriers (Diaz et al., 2018, Messias et al. 2019, Edwards et al., 2019, Bushuyev et al., 2020, Masel et al., 2021). Close to 50 high Technology Readiness Level (TRL) projects on CO2 to fuel exist in Europe and many of them will reach commercialisation in the near-term (before 2030). Please find a few examples below with the forecasted production of CO2-based fuel in near-term (within 5 years): -Norsk-efuel (DAC to jet-fuel)=> 100 Million ton of jet-fuel/year	Accepted.	Christian Breyer	LUT University	Finland
45631	38	30	39	2	Pressure and CO2 purity may not be constraints if a pipeline network for anthropogenic CO2 transportation is established in the midterm. For example, when transported at large scales, CO2 is typically transported in a liquid or supercritical form at pressures above 85 bar (Edwards et al. Applied Energy , 2019, 261, 114305) and high purities (J. Muragan et al. Carbon Research 2020, 6, 76; doi:10.3390/c6040076) . As of 2014, there are over 3,000 miles of high pressure pipeline which transport over 60 million tonnes of CO2 per year for enhanced oil recovery in 113 projects in the US alone (Mac Dowel, 2017, Nature Climate Change DOI:10.1038/NCLIMATE3231).	Noted. While this is an important discussion, we cannot include it because of space constraints.	Ana Machado	Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa	Portugal
17859	38	31	38	32	Urea CO_2 specifications are not “technological constraints”. They can be achieved using conventional compression and gas separation technologies. No new technological developments are required.	Noted. While this is an important discussion, we cannot include it because of space constraints.	Eve Tamme	Global CCS Institute	Belgium
69521	38	32	39	1	Urea production is a standard industrial process that does not offer any additional potential for CO2 mitigation, for 1) the carbon in the urea goes into the atmosphere in few weeks after it's been used (mostly in agriculture) and 2) there are reasons to believe that the use of nitrogen fertilisers must be and will be reduced in the future as 80% of the nitrogen does not end in the food but in natural ecosystems. China and India have zero growth policies, some EU countries have de-growth policies...	Noted. While this is an important discussion, we cannot include it because of space constraints.	Cédric PHILIBERT	Institut Français des Relations Internationales	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
1433	38		38		figure 6.13 ,What is the basis of color change?	Noted. Figure has been removed	Hamideh Dalaei	climatologist at Islamic Republic of IRAN Meteorological Organisation	Iran
3191	38		38		figure 6.13 has various colors for every region, but these colors are not defined.	Noted. Figure has been removed	Hamideh Dalaei	climatologist at Islamic Republic of IRAN Meteorological Organisation	Iran
43429	38		38		figure 6.13 has various colors for every region, but these colors are not defined.	Noted. Figure has been removed	sadegh zeyaeyan	Head of national center for forecasting and weather hazards management of Islamic Republic of Iran Meteorological Organization (IRIMO)	Iran
50335	38		38		figure 6.13 has various colors for every region, but these colors are not defined.	Noted. Figure has been removed	Government of Iran	Islamic Republic of Iran Meteorological Organization (IRIMO)	Iran
61215	38		38		Figure 6.13, the borders of the country are inaccurate and easily cause disputes. It is recommended to delete or use the map without borders	Noted. Figure has been removed	Jianguo WU	chinese research academy of environmental sciences	China
17871	39	3	39	4	The reported costs seem too high and the conclusions too severe. References: figure 3.4 in https://www.iea.org/reports/ccus-in-clean-energy-transitions/ccus-technology-innovation	Rejected. Our conclusions here are based on our synthesis of the literature	Eve Tamme	Global CCS Institute	Belgium
28611	39	4	39	4	and capturing from near pure streams of CO2 such as from gas processing, bioethanol and ammonia plant, is low capture cost. See IPCC WGIII SR on CCS (2005) Chp3.2	Noted. However, our discussion here largely pertains to capture from power and other energy sources	Tim Dixon	IEAGHG	United Kingdom (of Great Britain and Northern Ireland)
28615	39	4	39	7	Although recent work on second generation cature plant shows cost reductions of 67% from learning from the first operational generation plant. Giannaris, S. et al (2020). “Implementing a second generation CCS facility on a coal fired power station”, Greenhouse Gases: Science and Technology, 10(3), 506-518	Noted and paper has been cited.	Tim Dixon	IEAGHG	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
69525	39	6	39	7	The energy penalty of CO2 capture does not only increase the cost of electricity generation (or of industry production), it also alleviate the overall efficacy of CCS. The percentage of CO2 reduction is always smaller than the effiacy percentage of CO2 capture because of that, and this is compounded by the upsteam GHG emissions of fuel extraction and transport (which can and should be reduced but probably not to zero level). As note Pehl et alii 2017, " On a per-kilowatt-hour basis, the residual GHG emissions from fossil fuel CCS (mostly due to imperfect capture and upstream CH4 emissions) exceed the average power-sector emissions intensity required for 2 °C stabilization by a factor of five". (Pehl et alii, 2017, Understanding future emissions from low-carbon power systems by integration of life-cycle assessment and integrated energy modelling, Nature Energy, December, 939-945)	Noted. While this is an important discussion, we cannot include it because of space constraints.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
17507	39	7	39	7	perhaps mention explicitly that "further cost increases, so called CO2 Avoided Cost (Table 6.2)" Thanks	Accepted.	Alaa Al Khourdajie	IPCC	United Kingdom (of Great Britain and Northern Ireland)
29421	39	8	39	10	Levelized cost of electricity (LCOE) is often used for visualising the CCS cost. Please consider including LCOE in the table as it could make it much more informative.	Accepted.	Government of Norway	Norwegian Environment Agency	Norway
43877	39	8	39	10	There is one missing parameter that should be included in Table 6.2 and that is energy penalty. Energy penalty is a good point to discuss in C6 of the WGIII report because it is considered as one barrier (other than high investment cost) in what seems to be a hindrance in deploying CCUS technologies in fossil-fired power plants. House et al. (2009) [15] offers to descriptions for energy penalty: (1) it could be the fraction of fuel to be alloted for CCUS in order to do a specific work or (2) it could be an additional fuel requirement to compensate the loss in plant output due to the CCUS. The study in [15] could be a good reference for CCUS since it offers a way to reduce the impact of energy penalty, which is through capturing waste heat.	Noted. Energy penalty can be derived from the net efficiency	Vince Davidson Pacañot	University of the Philippines Diliman	Philippines
45489	39	8	39	8	Are the efficiencies HHV or LHV? For LHV they seem somewhat on the low side.	Accepted.	Kornelis Blok	Delft University of Technology	Netherlands
28383	39	9	39	10	CCS efficiencies states for biomass are lower than expected. While we are not aware of peer-reviewed literature that provides a more accurate reflection. However, Drax engineering data indicates anticipated efficiencies higher than these estimates.	Noted. While this is an important discussion, we cannot include it because of space constraints.	Michael Goldsworthy	Drax	United Kingdom (of Great Britain and Northern Ireland)
84323	39	9	39	10	Table 6.2: the meaning of last two columns is unclear except for negative emission (two bottom lines).	Noted. While this is an important discussion, we cannot include it because of space constraints.	Vincent MAZAURIC	Schneider Electric	France
64839	39	18	39	18	add reference Núñez-López, Vanessa, Ramón Gil-Egui, and Seyyed A. Hosseini. "Environmental and operational performance of CO2-EOR as a CCUS technology: a Cranfield example with dynamic LCA considerations." Energies 12, no. 3 (2019): 448.	Accepted.	Katherine Romanak	The Univeristy of Texas at Austin	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
70143	39	18			Menefee and Ellis 2020). However, when upstream considerations are included, the use of CCUS can result in net additive CO2 emissions in the range of 1.42-4.7 tons of CO2 for each ton removed (Jaramillo et al 2009; Mendelevitch 2013; Sekera and Lichtenberger 2020) https://pubs.acs.org/doi/abs/10.1021/es902006h ; https://ideas.repec.org/p/diw/diwwpp/dp1308.html ; https://doi.org/10.1007/s41247-020-00080-5	Noted. While this is an important discussion, we cannot include it because of space constraints.	Rayner Andersen	Department of Fisheries and Oceans	Canada
51363	39	22			than USD 350/t-CO2 (Fig 6.14 Hepburn et al. 2019).	Noted. While this is an important discussion, we cannot include it because of space constraints.	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
60457	39	22	39	23	This sentence is incomplete. Could be rephrase as follows: The success of these pathways therefore depends on the value of such fuels and on the values of other alternatives. Please note that in some cases, e.g. long haul aviation, there is no other drop-in alternative to CO2-based fuels. TNO report with numerous peer-reviewed references (https://www.at-aandrijftechniek.nl/wp-content/uploads/2020/09/TNO-Whitepaper-E-Fuels.pdf)	Accepted.	Célia Sapart	Université Libre de Bruxelles / CO2 Value Europe	Belgium
76317	39	22	39	23	This sentence is incomplete. Could be rephrase as follows: The success of these pathways therefore depends on the value of such fuels and on the values of other alternatives. Please note that in some cases, e.g. long haul aviation, there is no other drop-in alternative to CO2-based fuels. TNO report with numerous peer-reviewed references (https://www.at-aandrijftechniek.nl/wp-content/uploads/2020/09/TNO-Whitepaper-E-Fuels.pdf)	Accepted.	Deepak PANT	Flemish Institute for Technological Research (VITO)	Belgium
78811	39	22	39	23	"The success of these pathways therefore depends on the value of such fuels" : this sentence is uncomplet and could be completed by the following propositions : "…on the value, the CO2 emission avoidance, the CO2 sequestration duration and the existence of alternatives to CCU for some sectors to reach decarbonisation, of such a fuels." In the cas of long haul aviation sector, it seems that no alternative is clearly yet identified.The report from TNO, july 2020 : E-FUELS: TOWARDS A MORE SUSTAINABLE FUTURE FOR TRUCK TRANSPORT, SHIPPING AND AVIATION, gives an interesting view and comparison between H2 and efuels for aviation, including numbers of peer-reviewed papers. https://www.at-aandrijftechniek.nl/wp-content/uploads/2020/09/TNO-Whitepaper-E-Fuels.pdf	Accepted.	Sylvain Nizou	CEA	France
60461	39	25	39	34	It is not adequate to use a study more than 15 year old when discussing the public acceptance of emerging technologies (Daamen et al., 2006), especialy not when it comes to CCU. Could be replaced by: Jones et al. 2015, van Heek 2018 •Van Heek et al, 2017, Energy Proc., 114, 7212–7223 •Jones et al, 2015, Faraday Discussions, 183: 327-347.	Accepted.	Célia Sapart	Université Libre de Bruxelles / CO2 Value Europe	Belgium

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
64841	39	25	39	26	These references are old and theparagrpah does not highlight the most important issue around public acceptance which is a lack of understanding of the technology and its percieved relationship to fossil fuels. More updated references in clude Ashworth, P.; Sun, Y.; Ferguson, M.;Witt, K.; She, S. Comparing how the public perceive CCS across Australia and China. Int. J. Greenh. Gas Control 2019, 86, 125–133., Whitmarsh, L.; Xenias, D.; Jones, C.R. Framing effects on public support for carbon capture and storage. Palgrave Commun. 2019, 5, 1–10, and Romanak, K., Fridahl, M., & Dixon, T. (2021). Attitudes on Carbon Capture and Storage (CCS) as a Mitigation Technology within the UNFCCC. Energies, 14(3), 629.	Accepted.	Katherine Romanak	The Univeristy of Texas at Austin	United States of America
76321	39	25	39	34	It is not adequate to use a study more than 15 year old when discussing the public acceptance of emerging technologies (Daamen et al., 2006), especialy not when it comes to CCU. Could be replaced by: Jones et al. 2015, van Heek 2018 •Van Heek et al, 2017, Energy Proc., 114, 7212–7223 •Jones et al, 2015, Faraday Discussions, 183: 327-347.	Accepted.	Deepak PANT	Flemish Institute for Technological Research (VITO)	Belgium
83705	39	25	39	34	It is not adequate to use a study more than 15 year old when discussing the public acceptance of emerging technologies (Daamen et al., 2006), especialy not when it comes to CCU. Could be replaced by: Jones et al. 2015, van Heek 2018 •Van Heek et al, 2017, Energy Proc., 114, 7212–7223 •Jones et al, 2015, Faraday Discussions, 183: 327-347.	Accepted.	Christian Breyer	LUT University	Finland
64883	39	31	39	32	The sentence “Although few totally reject CCS, specific CCS projects have faced strong local resistance which has contributed to the cancellation of CCS projects (Terwel et al. 322012; L’Orange Seigo et al. 2014) is incorrect as written and also not supported by the references. Terwel refers to one well-known Barendrecht project and yet the sentence says “projects have faced strong local resistance” so this statement is unsupported as written. So a more correct statement supported by this paper would be “one project faced resistance that cancelled…”	Accepted.	Katherine Romanak	The Univeristy of Texas at Austin	United States of America
28613	39	35	40	2	The water use of CO2 capture can be managed to not increase, see references: Giannaris, S. et al (2020). “Implementing a second generation CCS facility on a coal fired power station”, Greenhouse Gases: Science and Technology, 10(3), 506-518; Magneschi et al (2017) "The Impact of CO2 Capture on Water Requirements of Power Plants", GHGT-13, Energy Procedia 114 6333-6347 ; IEAGHG (2020) “Understanding the cost of reducing water usage in coal and gas fired power plants with CCS”, IEAGHG 2020-09; IEAGHG (2011) "Evaluation and Analysis of Water Usage of Power Plants with CO2 Capture" IEAGHG 2010/05; IEAGHG (2020) "CCS and the Sustainable Development Goals", IEAGHG 2020-14; Mikunda et al (2020) "CCS and the Sustainable Development Goals", International Journal of Greenhouse Gas Control (submitted 17 Nov 2020); also IPCC (2018) SR1.5 Chap 5 p500 which cites Magneschi. The papers cited here in SOD Chp6 (Rosa, Lui, Yang) whilst recent (2019,2020) have been checked and found to have chosen water use assumptions based only on papers from 2010 and 2011 (Rosa), 2012 (Lui) and 2011-2013 (Yang) and so are out of date. [Why were they selective in their assumptions?]	Accepted. Caveat on water use remaining neutral in some cases has been added.	Tim Dixon	IEAGHG	United Kingdom (of Great Britain and Northern Ireland)
60463	39	35	39	38	This statement applies to CCS technologies and both references refer to CCS and not to CCU so the word CCUS should be replaced by CCS everywhere in this section.	Rejected. Several chemical and resource use criteria would increase in the capture stage, which is common to CCS and CCU	Célia Sapart	Université Libre de Bruxelles / CO2 Value Europe	Belgium

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
76323	39	35	39	38	This statement applies to CCS technologies and both references refer to CCS and not to CCU so the word CCUS should be replaced by CCS everywhere in this section.	Refer to comment 60463	Deepak PANT	Flemish Institute for Technological Research (VITO)	Belgium
78813	39	35	39	38	It is preferable to separate CCU and CCS regarding water consumption. Some CCU process even generate water (Power to méthanol Ref: https://www.sciencedirect.com/science/article/pii/S0306261920312563#b0055) . Please only mention CCS regarding this water consumption.	Refer to comment 60463	Sylvain Nizou	CEA	France
83707	39	35	39	38	This statement applies to CCS technologies and both references refer to CCS and not to CCU so the word CCUS should be replaced by CCS everywhere in this section.	Refer to comment 60463	Christian Breyer	LUT University	Finland
2655	39	36	37	28	“Water withdrawals …”: I don't understand this sentence.	Accepted.	Jan Wohland	ETH Zurich	Switzerland
29423	39	36	39	38	Please consider other sources here. It says "Water withdrawals for CCUS are 25-200%, higher than plants with (without?) CCUS". This statement could benefit from a broader assessment of relevant litterature. The use of cooling water, and the trade-offs related to this, will be project and location spesific. Please consider to make reference to, and revise the text in accordance with: IEAGHG, 2010: "Evaluation and Analysis of Water Usage of Power Plants with CO2 Capture", Magneschi et al, 2017: "The Impact of CO2 Capture on Water Requirements of Power Plants", GHGT-13, Energy Procedia 114 (2017) 6333-6347, IEAGHG, 2020: “Carbon Capture and Storage and the Sustainable Development Goals”, Giannaris, bruce, et. al., 2020: "Implementing a second generation CCS facility on a coal fired power station – results of a feasibility study to retrofit SaskPower’s Shand power station with CCS", DOI: 10.1002/ghg.1989.	Accepted.	Government of Norway	Norwegian Environment Agency	Norway
1561	39	37	39	37	"25-200%, higher than plants with CCUS" should be "25-200% higher than plants without CCUS"?	Accepted.	Martin Green	UNSW Sydney	Australia
17505	39	37	29	27	without instead of with? CCUS	Accepted.	Alaa Al Khourdajie	IPCC	United Kingdom (of Great Britain and Northern Ireland)
55689	39	37	39	37	Clarify sentence: "… withdrawals for CCUS are 25-200% higher than plants with CCUS …"	Accepted.	Government of United States of America	U.S. Department of State	United States of America
64131	39	37	39	37	Word out to be add and the sentence "Water withdrawal for CCUS are 25-200% higher than plants with CCUS" may be rephrased as "Water withdrawal for CCUS are 25-200% higher than plants without CCUS".	Accepted.	Ghulam Rasul Athar	Pakistan Atomic Energy Commission	Pakistan
79629	39	37			Unclear sentence, the second with should read without?	Accepted.	Marc Daras	CentraleSupelecAlumni	France
86531	39	37	39	37	higher than plants WITHOUT CCUS	Accepted.	raphael Slade	Imperial college	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
52273	39				Table 6.2: Oil + CCS , Natural Gas + CCS are the most efficient and cost effective and this needs to be emphasized in the text.	Noted. While this is an important discussion, we cannot include it because of space constraints.	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
47837	40	1	40	4	Fig 6.14 is not helpful in the context of presenting the develoment stages of different CCU technologies and their respective life cycle impacts	Noted. While this is an important discussion, we cannot include it because of space constraints.	Patrick Lamers	NREL	United States of America
84325	40	2	40	3	Figure 6.14: are the potentials dependant to the abatements of previous options?	Accepted. Text modified	Vincent MAZAURIC	Schneider Electric	France
28457	40	4	40	4	Figure 6.14 shows an enormous economically beneficial potential on CO2 utilisation, I think this could be further stressed and focussed on in the report. Especially since the range between high and low scenario is this big, it means targeted policies are required to get to the upper end.	Noted. While this is an important discussion, we cannot include it because of space constraints.	Naud Loomans	Eindhoven University of Technology	Netherlands
29425	40	5	40	6	Consider rephrasing. It says that "CCUS always adds cost". This is not always true. CCS adds cost but might still be cost-effective. Several CO2 utilisation routes also leads to valuable products, and there can be economic benefits for the whole process. As a consequence, policy instruments are needed for CCS, but policy instruments are not always needed for CCUS.	Noted. While this is an important discussion, we cannot include it because of space constraints.	Government of Norway	Norwegian Environment Agency	Norway
45633	40	5	40	11	Again the concepts of CCS and CCU are mixed, which may lead to an erroneous evaluation. In the case of CCU a recent study shows that when electricity costs fall below 4 cents/kWh and energy efficiency is at least 60%, all products generated from CO2 electrolysis will become competitive with current market prices for these products derived from fossil fuel sources. (De Luna et al., 2019, Science, 364, 6438).	Noted. While this is an important discussion, we cannot include it because of space constraints.	Ana Machado	Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa	Portugal

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60465	40	5	40	11	The term CCUS (Carbon Capture Utilisation and Storage) is still used here but not clearly defined and at first sight this term discusses only Carbon Capture and Storage (CCS) technologies and not the utilisation phase. CSS and Carbon Capture and Use (CCU) distinctly differ regarding their CO2 reduction potential, the underlying technical processes and outcomes, their effects on climate mitigation, their business models and their environmental policy targets. Therefore, presenting commingling CCS and CCU does not do justice to the specific characteristics of the two concepts and could be counterproductive for the further development particularly of CCU. This is especially important while discussing the business model, as CCS only has a cost while CCU create a value in producing valuable products. Therefore the term CCUS should be separated in CCS and CCU and both options should be clearly addressed independently (Cuéllar-Franca and Azapagic, 2015, Bruhn et al., 2016, Arning et al., 2019). Broad policy and regulatory changes that may support the appropriate scale-up of CO2 utilization include creating carbon prices of around $40 to $80 per tonne of CO2, increasing over time, to penalize CO2 emissions and to incentivize verifiable CO2 emissions reductions and removals from the atmosphere (Hepburn et al., 2019). It is crucial to foster demand for and competitiveness of climate neutral, circular economy solutions through demand-side measures, but also to investigate and develop alternative or complementary options for carbon pricing mechanisms considering their impact on emissions, markets and investments at all levels. (HLEG on EIE, 2019). •Bruhn et al., 2016, Environmental Science & Policy, 60, 38–43.•Arning et al. 2019, Energy Policy, 125, 235–249.•Cuéllar-Franca and Azapagic, 2015, J.CO2.Utili., 9, 82-102.•Hepburn et al., 2019, Nature, 575, 87-97. •HLEG on EII, 2019: Masterplan for a Competitive Transformation of EU EII Enabling a Climate-neutral, Circular Economy by 2050, High Level Expert Group on Energy Intensive industries.	Refer to comment 60465	Célia Sapart	Université Libre de Bruxelles / CO2 Value Europe	Belgium

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
76325	40	5	40	11	The term CCUS (Carbon Capture Utilisation and Storage) is still used here but not clearly defined and at first sight this term discusses only Carbon Capture and Storage (CCS) technologies and not the utilisation phase. CSS and Carbon Capture and Use (CCU) distinctly differ regarding their CO2 reduction potential, the underlying technical processes and outcomes, their effects on climate mitigation, their business models and their environmental policy targets. Therefore, presenting commingling CCS and CCU does not do justice to the specific characteristics of the two concepts and could be counterproductive for the further development particularly of CCU. This is especially important while discussing the business model, as CCS only has a cost while CCU create a value in producing valuable products. Therefore the term CCUS should be separated in CCS and CCU and both options should be clearly addressed independently (Cuéllar-Franca and Azapagic, 2015, Bruhn et al., 2016, Arning et al., 2019). Broad policy and regulatory changes that may support the appropriate scale-up of CO2 utilization include creating carbon prices of around $40 to $80 per tonne of CO2, increasing over time, to penalize CO2 emissions and to incentivize verifiable CO2 emissions reductions and removals from the atmosphere (Hepburn et al., 2019). It is crucial to foster demand for and competitiveness of climate neutral, circular economy solutions through demand-side measures, but also to investigate and develop alternative or complementary options for carbon pricing mechanisms considering their impact on emissions, markets and investments at all levels. (HLEG on EIE, 2019). •Bruhn et al., 2016, Environmental Science & Policy, 60, 38–43.•Arning et al. 2019, Energy Policy, 125, 235–249.•Cuéllar-Franca and Azapagic, 2015, J.CO2.Utili., 9, 82-102.•Hepburn et al., 2019, Nature, 575, 87-97. •HLEG on EII, 2019: Masterplan for a Competitive Transformation of EU EII Enabling a Climate-neutral, Circular Economy by 2050, High Level Expert Group on Energy Intensive industries.	Refer to comment 60465	Deepak PANT	Flemish Institute for Technological Research (VITO)	Belgium

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
83709	40	5	40	11	The term CCUS (Carbon Capture Utilisation and Storage) is still used here but not clearly defined and at first sight this term discusses only Carbon Capture and Storage (CCS) technologies and not the utilisation phase. CSS and Carbon Capture and Use (CCU) distinctly differ regarding their CO2 reduction potential, the underlying technical processes and outcomes, their effects on climate mitigation, their business models and their environmental policy targets. Therefore, presenting commingling CCS and CCU does not do justice to the specific characteristics of the two concepts and could be counterproductive for the further development particularly of CCU. This is especially important while discussing the business model, as CCS only has a cost while CCU create a value in producing valuable products. Therefore the term CCUS should be separated in CCS and CCU and both options should be clearly addressed independently (Cuéllar-Franca and Azapagic, 2015, Bruhn et al., 2016, Arning et al., 2019). Broad policy and regulatory changes that may support the appropriate scale-up of CO2 utilization include creating carbon prices of around $40 to $80 per tonne of CO2, increasing over time, to penalize CO2 emissions and to incentivize verifiable CO2 emissions reductions and removals from the atmosphere (Hepburn et al., 2019). It is crucial to foster demand for and competitiveness of climate neutral, circular economy solutions through demand-side measures, but also to investigate and develop alternative or complementary options for carbon pricing mechanisms considering their impact on emissions, markets and investments at all levels. (HLEG on EIE, 2019). •Bruhn et al., 2016, Environmental Science & Policy, 60, 38–43.•Arning et al. 2019, Energy Policy, 125, 235–249.•Cuéllar-Franca and Azapagic, 2015, J.CO2.Utili., 9, 82-102.•Hepburn et al., 2019, Nature, 575, 87-97. •HLEG on EII, 2019: Masterplan for a Competitive Transformation of EU EII Enabling a Climate-neutral, Circular Economy by 2050, High Level Expert Group on Energy Intensive industries.	Refer to comment 60465	Christian Breyer	LUT University	Finland
85973	40	5	40	5	Suggest clarification: "… CCUS always adds costs…" seems at odds with the figure directly above it, indicating negative costs for a number of CO2 utilisation pathways (e.g. EOR, methanol, etc.) Would be worth clarifying this statement in light of Figure 6.14.	Refer to comment 60465	Government of Australia	Department of Industry, Science, Energy and Resources	Australia
17509	40	7	40	7	"2020)The" ==> "2020). The"	Accepted.	Alaa Al Khourdajie	IPCC	United Kingdom (of Great Britain and Northern Ireland)
61981	40	7	40	7	Typo: change "pricing (Haszeldine 2016; Kang et al. 2020)The recent" to "pricing (Haszeldine 2016; Kang et al. 2020). The recent"	Accepted.	Esa Vakkilainen	LUT University, Lappeenranta	Finland
80135	40	7	40	9	45Q tax credits were recently reformed to have a relatively short recapture period, meaning that essentially tax credits cannot be "recaptured," or lost by investors, after as little as three years if stored carbon leaks. This asymmetry between the short extent of legal liability for leaks in CCUS and the long lifespan of many of the emissons they attempt to offset in the atmosphere is a potential governance concern. Citation: Section 45Q(f)(4) of the Internal Revenue Code. As a law student, I cannot formally offer legal advice, but many law firms additionally offer guidance documents on their websites that may be helpful as background, albeit not as scholarly sources as what is already cited or the IRC itself: https://www.kirkland.com/publications/blog-post/2021/01/section-45q-final-regulations	Noted. While this is an important discussion, we cannot include it because of space constraints.	Robin Happel	Yale Center for Environmental Law & Policy	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
8413	40	12	41	21	In many countries (such as China and South East Asia), food waste is in abundance which is an energy source. This resource can be exploited and be converted to methane and eventually electricity. This resource is often under estimated.	Noted. The role of waste resource is already highlightd: "Wastes and residues (e.g., agricultural, forestry, animal manure, processing) or biomass grown on degraded, surplus, and marginal land provides opportunities for cost-effective and sustainable bioenergy at significant scale (medium confidence) "	Otto Poon	President, Hong Kong Academy of Engineering Sciences.	China
8983	40	12	44	36	Sub-section “Bioenergy”. Bioenergy is a very controversial issues. I suggest to take into account, or at least to quote, further criticism present in the literature, for example, Giampietro and Mayumi (Giampietro, M., and Mayumi, K., 2015. The Biofuel Delusion - The Fallacy of Large Scale Agro-Biofuels Production. Routledge) and Spagnolo et al. (Spagnolo, S., and Coauthors, 2020: Sustainability assessment of bioenergy at different scales: An emergy analysis of biogas power production. Journal of Cleaner Production 277 (2020) 124038. https://doi.org/10.1016/j.jclepro.2020.124038), the latter addressing the real environmental cost of manure used in bioenergy production plants.	Noted. The controversial role of bioenergy is already explicitly highlighted. The second ref suggested has been added to support the "environmental cost of manure used in bioenergy production plants".	Francesco Gonella	Ca' Foscari University of Venice, Italy	Italy
17367	40	12	40	12	Biomass section is too long if the potential of the source is considered. Land use efficiency, which is the most problematic, is not mentioned sufficiently. It should be quantified.	Noted. Section length aligned with plans. Land use efficiency is mentioned as "Assessing the potential for purpose-grown bioenergy is challenging due to its far-reaching linkages to issues beyond the energy sector, including competition with land for food production and forestry"	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
28385	40	12	44	36	1.This section places undue focus on advanced microbial solutions and dedicated energy crops, rather than existing integrated systems & supply chains, notably in the wood pellet sector 2.In a future where land is scarce, dedicating land to bioenergy is unlikely to be an economic or sustainable solution except where part of a land use system providing wider ecosystem benefits (e.g. enhancing biodiversity/flood prevention) 3.Existing industry supply chains (outside of liquid biofuels) are heavily focused on sourcing low value waste and residues from forestry and agriculture, not on second generation platforms or dedicated energy crops, on the basis these represent the most cost-effective and sustainable feedstocks 4.Bioenergy has significant potential to be integrated into part of sustainable land use systems, providing an array of outputs to food, feed, fibre and energy markets, in accordance with hierarchy of uses (e.g. only lowest value material going to energy). This provides greatest opportunity for economically and environmentally sustainable supply chain 5. Woody bioenergy has significant potential to offer protection of forests by encouraging investment and supporting sustainable management practices 6. Land use change (and often overlooked, land management change) should not be considered to only be negative for bioenergy. Where demand supports extensification or intensification of high carbon stock land (e.g. forestry), direct and indirect climate impacts can be postive. Greater consideration and focus should therefore be placed on expansion of existing integrated systems & supply chains, rather than theoretical potential of dedicated novel sources. Not least as it is duly recognised that in D2 of summary for policymakers that “In the land sector, mitigation is most successful where synergies with other functions of land are addressed in an equitable manner.” Equally, greater consideration should be given of supply/demand linkages of woody bioenergy with	Taken into account. 1) A sentence has been added to highlight the current bioenergy uses 2) On land-use: see comment above 3)Agreed, a sentecne has been added to clarify: Current bioenergy production relies and traditional biomass, residues from forestry and agriculture, food crops in some regions, and wastes. 4) integration. This topic pertains more to biomass supply rather than in the energy chapter, but a sentence and one of the suggested ref has been added 5) forest management. This topic pertains more to biomass supply rather than in the energy chapter, but a sentence and one of the suggested ref has been added 6) land-use management. This topic pertains more to biomass supply rather than in the energy chapter, but a sentence and one of the suggested ref has been added	Michael Goldsworthy	Drax	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
28387	40	12	44	36	Supporting literature In one of the main sourcing areas for wood pellet, the US South, around 85% of forests are privately owned and a key dynamic reflected is that increased demand is associated with more investment in forests, in particular leading to more carbon sequestered and stored as a result of healthy market demand. Aguilar, F.X. et al. found 'A one percentage-point increase in overlap of wood pellet mill procurement areas, denoting greater competition, was associated with larger C stocks in above and belowground live (2.07 tons C/ha; p = 0.00) and standing-dead (0.06 tons C/ha; p = 0.00) trees pools, and in soils (1.32 tons C/ha; p = 0.02).' They comment 'On the balance, there has been a net contemporaneous positive effect.' Duden et al. modelled impacts of wood pellet demand on forests in US SE and found that under a high pellet demand scenario there was greater retention of natural timberland (2,000-7,500km2) and increased establishment of pine plantation (8,000-20,000km2). Nepal also invetigated projected developments in timber price/harvest/inventory resulting from a wood energy demand increase in the US from 56 million m3 to 125 million m3 (High energy scenario) compared to a baseline increase of 56million m3 to 64 million m3 and found the following: Impact on non-sawtimber (pulpwood, sawmill residuals and logging residues) •Increase in wood energy demand for the high energy scenario is projected to bet met by largely through use of pulpwood: 19 million m3 additional pulpwood and 37 million m3 pulpwood diverted from existing markets •The price of feedstock for wood fuel increases from $18/t to $24/t (compared to	Accepted. Thanks for the additional resources, some have been added to the chapter to address the points above	Michael Goldsworthy	Drax	United Kingdom (of Great Britain and Northern Ireland)
28511	40	12	44	36	This section does not cover a number of opportunities to combine biogenic carbon from biomass with renewable hydrogen for the enhancement of the biofuel yield. This is an important omission and should be corrected. More details are available in https://www.ieabioenergy.com/blog/publications/new-publication-drop-in-biofuels-the-key-role-that-co-processing-will-play-in-its-production/, https://www.sciencedirect.com/science/article/abs/pii/S0360544216303668 and https://portal.research.lu.se/portal/files/31711760/Biogenic_carbon_dioxide_as_feedstock_for_production_of_chemicals_and_fuels_IMES_report_103.pdf.	Taken into account. A sentence has been added: Also, hydrogen can be used to enhance biofuels output in gasification-based biorefineries (REF)	Pierpaolo Cazzola	International Transport Forum	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
48125	40	12	40	18	Bioenergy " could be particularly valuable for hard-to-decarbonise sectors with limited alternatives to fossil fuels (e.g., aviation, heavy industry), and can be used with CCUS to create negative emissions." This statement is misleading. Bioenergy, when burned, creates pollution that kills people. This should be mentioned. Bioenergy with CCS suffers the same opportunity cost problems as fossils with CCS: Jacobson, M.Z., The health and climate impacts of carbon capture and direct air capture, Energy and Environmental Sciences, 12, 3567-3574, doi:10.1039/C9EE02709B, 2019 and also Chapter 3 of Jacobson, M.Z., 100% Clean, Renewable Energy and Storage for Everything, Cambridge University Press, New York, 427 pp., 2020. Better alternatives for aviation are electric and hydrogen fuel cell, which produce no pollution. There are many electric alternatives to heavy industry as well (see Chapter 2 of the book above).	Noted. Direct emissions are explicitly mentioned: "The broader environmental implications of bioenergy extend beyond direct combustion products that impact air quality and include land use and land use change emissions, non-CO2 GHG emissions, water use, fertilizer use, and biodiversity (high confidence)."	Mark Jacobson	Stanford University	United States of America
79631	40	12			In the whole § on bioenergy, the status of CO2 emission is unclear. It might have been clarified earlier in an energy primer for instance. The CO2 emission from biomass is not a fossil CO2. It returns to the atmosphrere from which it has been withdrawn. Then, the question is the sustainable production of biomass, and an evential impact interms of LULUCF. In a second step, BECCS allow a net withdrawal of CO2 from the atmosphere. In this part the benefit is mostly underlined with CDR, while the direct use of biomass is already a benefit and while massive ccus is not yet available.	Accepted. This point has been clarified	Marc Daras	CentraleSupelecAlumni	France
11731	40	13	40	18	"The hard-to-decarbonise-sectors, i.e. agriculture"; even if land was not used for farming there would still be emissions.	Revised text: Bioenergy is potentially a high-value and large-scale mitigation option. It can support many different parts of the energy system, and it could be particularly valuable for hard-to-decarbonize sectors with limited alternatives to fossil fuels (e.g., aviation, heavy industry) and to produce chemicals and products	The Royal Swedish Academy of Agriculture and Forestry (Group Review)	Kung. Skogs-och Lantbruksakademien	Sweden
45893	40	13	40	13	Please fundamentally reconsider the feasibility of BECCS as a CDR-technology. COMMENT: Many of the models described in chapter 3 are built on the claim "Bioenergy is potentially a high-value and large-scale mitigation option", but proof is missing. Practical experience is lacking and "life-cycle climate impacts from bioenergy" are termed to be "subject to large uncertainties" (see p. 42f) or even negated (Brack and King 2020). --- Brack, D., King, R., 2020, Net Zero and Beyond – What Role for Bioenergy with Carbon Capture and Storage?, Energy, Environment and Resources Programme, Chatham House, January 2020.	Accepted. This point has been clarified: There exists a high potential for CDR through BECCS, but issues and concerns around its sustainability and scale-up will influence the viability of BECCS (high confidence)	Government of Germany	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety International Climate Policy	Germany
63643	40	13	40	18	The most prevalent use of bioenergy is thermal energy for industrial process heat and building heat, including (and increasingly) in district energy systems. This is also the most efficient and cost effective use of biomass for energy and most often uses local sources of biomass, largely residues from forestry and agriculture, minimizing environmental concerns and stimulating local economy. This should be noted at the beginning of section 6.4.2.6., with other potential future uses discussed after.	Rejected. This comment isn't really supported by solid references. This sentence has been added to clarify how bioenergy is currently used: Current bioenergy production relies and traditional biomass, residues from forestry and agriculture, food crops in some regions, and wastes.	Government of Canada	Environment and Climate Change Canada	Canada

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
80631	40	13	41	2	Bioenergy should not be considered as an efficient mitigation option. Particularly, bioenergy, especially harvesting forest biomass for energy, is not carbon neutral in the near-term—with a carbon deficit for many years, generally several decades to a century—that is crucial for mitigating emissions and avoiding hitting the 1.5°C mark. Danielle Venton, Core Concept: Can bioenergy with carbon capture and storage make an impact?, PNAS (2016); Leturcq, P. (2020) GHG Displacement Factors of Harvested Wood Products: the Myth of Substitution, Nature Scientific Reports 10:1–9; Sterman J. D., et al. (2018) Does replacing coal with wood lower CO2 emissions? Dynamic lifecycle analysis of wood bioenergy, Envtl. Research Letters 13(015007):1–10, 1 ("We simulate substitution of wood for coal in power generation, estimating the parameters governing NPP and other fluxes using data for forests in the eastern US and using published estimates for supply chain emissions. Because combustion and processing efficiencies for wood are less than coal, the immediate impact of substituting wood for coal is an increase in atmospheric CO2 relative to coal. The payback time for this carbon debt ranges from 44–104 years after clear-cut, depending on forest type—assuming the land remains forest. Surprisingly, replanting hardwood forests with fast-growing pine plantations raises the CO2 impact of wood because the equilibrium carbon density of plantations is lower than natural forests. Further, projected growth in wood harvest for bioenergy would increase atmospheric CO2 for at least a century because new carbon debt continuously exceeds NPP. Assuming biofuels are carbon neutral may worsen irreversible impacts of climate change before benefits accrue. Instead, explicit dynamic models should be used to assess the climate impacts of biofuels."). Even when the bioenergy comes from burning forest residue, research shows that bioenergy is not carbon neutral within 10 years and often not carbon neutral for much longer. Repo, A., et al. (2012) Forest bioenergy climate impact can be improved by allocating forest residue removal, Global Change Biology Bioenergy, 4:202-212, 209 ("The results of this study show that using forest residues for energy production is neither GHG emission free nor carbon neutral. This is mainly	Noted. These are all valid concern already addressed in the report. We have added some of the sources suggested. While bioenergy is not carbon neutral, it can provide some emissions savings and a key feature of bioenergy in long-term projections is its ability to potentially remove carbon from the athmosphere. By capturing CO2 some bioenergy routes can produce net-negative GHG emissions in what is called bioenergy with CO2 capture and storage (BECCS) . There exists a high potential for carbon dioxide removal (CDR) through BECCS, but issues and concerns around its sustainability, impact on national security, land and water competition with food, biodiversity, and scale-up potential will influence the viability of BECCS (high confidence)	Durwood Zaelke	Institute for Governance & Sustainable Development	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
80775	40	13	41	2	Bioenergy should not be considered as an efficient mitigation option. Particularly, bioenergy, especially harvesting forest biomass for energy, is not carbon neutral in the near-term—with a carbon deficit for many years, generally several decades to a century—that is crucial for mitigating emissions and avoiding hitting the 1.5°C mark. Danielle Venton, Core Concept: Can bioenergy with carbon capture and storage make an impact?, PNAS (2016); Leturcq, P. (2020) GHG Displacement Factors of Harvested Wood Products: the Myth of Substitution, Nature Scientific Reports 10:1–9; Sterman J. D., et al. (2018) Does replacing coal with wood lower CO2 emissions? Dynamic lifecycle analysis of wood bioenergy, Envtl. Research Letters 13(015007):1–10, 1 ("We simulate substitution of wood for coal in power generation, estimating the parameters governing NPP and other fluxes using data for forests in the eastern US and using published estimates for supply chain emissions. Because combustion and processing efficiencies for wood are less than coal, the immediate impact of substituting wood for coal is an increase in atmospheric CO2 relative to coal. The payback time for this carbon debt ranges from 44–104 years after clear-cut, depending on forest type—assuming the land remains forest. Surprisingly, replanting hardwood forests with fast-growing pine plantations raises the CO2 impact of wood because the equilibrium carbon density of plantations is lower than natural forests. Further, projected growth in wood harvest for bioenergy would increase atmospheric CO2 for at least a century because new carbon debt continuously exceeds NPP. Assuming biofuels are carbon neutral may worsen irreversible impacts of climate change before benefits accrue. Instead, explicit dynamic models should be used to assess the climate impacts of biofuels."). Even when the bioenergy comes from burning forest residue, research shows that bioenergy is not carbon neutral within 10 years and often not carbon neutral for much longer. Repo, A., et al. (2012) Forest bioenergy climate impact can be improved by allocating forest residue removal, Global Change Biology Bioenergy, 4:202-212, 209 ("The results of this study show that using forest residues for energy production is neither GHG emission free nor carbon neutral. This is mainly	See answer to comment #80631.	Gabrielle Dreyfus	Institute for Governance & Sustainable Development	United States of America
85377	40	13	40	13	Proposed change: Bioenergy is potentially a high-value and large-scale mitigation option. It can support many different parts of the energy system, could be particularly valuable for hard-to-decarbonise sectors with limited alternatives to fossil fuels (e.g., aviation, heavy industry), and can be used with CCUS to create negative emissions. The technology for large-scale production of biofuels from second generation processes, however, is not competitive at the moment, and growing dedicated bioenergy crops raises a broad set of sustainability concerns . Its long-term role in low-carbon energy systems is therefore uncertain and depends on specific policies to increase its competitiveness and address the sustainability concerns. (high confidence).	Taken into account. This sentence has been edited: Bioenergy is potentially a high-value and large-scale mitigation option. It can support many different parts of the energy system, and it could be particularly valuable for hard-to-decarbonize sectors with limited alternatives to fossil fuels (e.g., aviation, heavy industry), to produce chemicals and products, and potentially in combination with CCS to provide carbon dioxide removal (CDR). Current bioenergy production relies on traditional biomass, residues from forestry and agriculture, food crops in some regions, and wastes. The technology for large-scale production of biofuels from second generation processes, however, is not competitive, and growing dedicated bioenergy crops raises a broad set of sustainability concerns. Its long-term role in low-carbon energy systems is therefore uncertain (high confidence).	Neil Dickson	ICAO	Canada

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
47839	40	16	40	18	The text should specify 'price' competitiveness of 2G biofuels, which goes beyond 2G production costs and needs to include (at leats mention) unfair price competition from fossil fuels - whose external effects and consequences are not reflected in the price. The competitiveness question could also be discussed from a carbon perspective - which is where the justification for 2G comes from. The present text does not reflect this nuance and is misleading.	Accepted. Added "price"	Patrick Lamers	NREL	United States of America
48005	40	16	40	18	This excerpt should mention the large scale use of first generation biofuels in many countries and regions, which already deliver significant GHG emissions reductions in land transport and is expected to remain doing so at least in the near- to mid-term. Moreover, while sustainability is indeed a concern, there is a growing body of literature on the best ways of sustainably producing biofuels, mitigating potential trade-offs and promoting synergies and co-benefits. This has been highlighted and summarized in other chapters of the report (e.g. Chapter 3, p. 93, l. 45-47 and p. 94, l. 1-7; Chapter 7, p. 96, l. 17-26 and p. 97, l. 11-19). In addition, although uncertainties due exist regarding the amount of bioenergy and BECCS in future energy systems, it should be noted that "While CDR is likely necessary for net-zero energy systems, the scale and mix of strategies is unclear – nonetheless some combination of BECCS and DAC are likely to be part of net-zero energy systems (high confidence)." (Chapter 6, p. 93, l. 40-41). Therefore, the following alternative wording to this excerpt is proposed: “While conventional biofuels are already a reality, the technology for large-scale production of biofuels from second generation processes is not competitive yet. Moreover, growing bioenergy crops raises sustainability concerns that negatively impact public acceptance of this option, even though there is a growing body of literature on the ways to mitigate negative impacts and promote synergies and co-benefits. Its long-term role is therefore uncertain, although some combination of BECCS is likely to be part of net-zero energy systems.”	See response to comment #50921	Marcelo moreira	UNICAMP - Agroicone	Brazil

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
50925	40	16	40	18	This excerpt should mention the large scale use of first generation biofuels in many countries and regions, which already deliver significant GHG emissions reductions in land transport and is expected to remain doing so at least in the near- to mid-term. Moreover, while sustainability is indeed a concern, there is a growing body of literature on the best ways of sustainably producing biofuels, mitigating potential trade-offs and promoting synergies and co-benefits. This has been highlighted and summarized in other chapters of the report (e.g. Chapter 3, p. 93, l. 45-47 and p. 94, l. 1-7; Chapter 7, p. 96, l. 17-26 and p. 97, l. 11-19). In addition, although uncertainties due exist regarding the amount of bioenergy and BECCS in future energy systems, it should be noted that "While CDR is likely necessary for net-zero energy systems, the scale and mix of strategies is unclear – nonetheless some combination of BECCS and DAC are likely to be part of net-zero energy systems (high confidence)." (Chapter 6, p. 93, l. 40-41). Moreover, almost all projections, models and studies to date in literature and by major entities such as IEA, IRENA and previous IPCC reports put bioenergy as a key enabler of the low carbon economy transition. In the face of that strong body of evidence, the statement that bioenergy's long-term role in low carbon energy systems is uncertain is certainly not warranted, and more akin to an ideological perception. The fact that it is folowed by a "high confidence" bracket is all the more ultrageous. Therefore, the following alternative wording to this excerpt is proposed: "While conventional biofuels are already a reality, the technology for large-scale production of biofuels from second generation processes needs policy support to reach competitiveness. Moreover, growing dedicated bioenergy crops raises sustainability concerns, but there is a growing body of literature on the ways to mitigate negative impacts and promote synergies and co-benefits. There are conflicting views about the long term role of bioenergy in low carbon energy systems, although some combination of bioenergy with and without CCS is likely to be part of net-zero energy systems (high confidence)"	Taken into account. This sentence has been added: "Current bioenergy production relies and traditional biomass, residues from forestry and agriculture, food crops in some regions, and wastes" And "While conventional biofuels are already a reality, the technology for large-scale production of biofuels from second generation processes is not currently price competitive, and growing dedicated bioenergy crops raises a broad set of sustainability concerns. Its long-term role in low-carbon energy systems is therefore uncertain although some combination of bioenergy with and without CCS is likely to be part of net-zero energy systems (high confidence)."	Government of Brazil	Ministry of Foreign Affairs of Brazil	Brazil
79633	40	16			The sentence should read: "Concerning transport, the technology for large scale production of liquid biofuel from cellulosic materials (second generation biofuels) is not competitive with fossil liquid biofuels in the present market conditions ". The question of commpetiveness with present energy carriers is not pertinent on the long term, if for instance a real carbon tax is implemented, or if regulation impose it as already the case partly for 1st generation. The question is the affordability of the transport service.	Taken into account. Text has been clarified "is not currently price competitive"	Marc Daras	CentraleSupelecAlumni	France
47841	40	18	40	18	Biofuels long-term role in decarbonizing hard-to-decarbonzie sectors should not be (and is not) uncertain if there is a policy and societal push for sustainable biofuels from waste feedstock or purpose grown feedstock that generates co-benefits on a landscape scale (e.g., present nutrient run-off and leaching from food cropping systems). The statement at present is simplified and misleading and requires revision.	Noted. The overall role of bioenergy remains uncertain given opposing perspectives in the literature	Patrick Lamers	NREL	United States of America
55691	40	18	40	18	This may be an oversimplification given information later in the chapter regarding various roles bioenergy can play. Rephrase.	Taken into account. "Its long-term role in low-carbon energy systems is therefore uncertain" has been changed to "Its long-term role in low-carbon energy systems is therefore uncertain although some combination of bioenergy with and without CCS is likely to be part of net-zero energy systems"	Government of United States of America	U.S. Department of State	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
70145	40	18			(Esposito et al. 2019). However, the use of the US45Q tax credits is further complicated by a historical failure to document successful implementation of nearly 90% of claimed storage (Frazin 2020; Hulac 2020). Existing monitoring and data tracking systems may need to be government-operated in order to ensure proper documentation and utilization in line with climate mitigation goals. https://thehill.com/policy/energy-environment/495526-government-probe-finds-companies-claiming-carbon-capture-tax-credit ; https://www.rollcall.com/2020/04/30/treasury-ig-a-decade-of-carbon-capture-tax-credits-were-faulty/	These seem aligbed with the current text	Rayner Andersen	Department of Fisheries and Oceans	Canada
45895	40	19	40	23	It seems appropriate to integrate biodiversity in this discussion as well, as it has an intrinsic value beyond ecosystems services, which should be considered. Biomass extraction for bioenergy production also extracts biomass from various natural cycles (see chapter 7 and 12.5).	Accepted. added in a later sentence: There exists a high potential for carbon dioxide removal (CDR) through BECCS, but issues and concerns around its sustainability, impact on national security, land and water competition with food, biodiversity, and scale-up potential will influence the viability of BECCS (high confidence)	Government of Germany	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety International Climate Policy	Germany
63645	40	19	41	2	The final sentence in this paragraph should be moved to the start. Note that wastes and residues are the most commonly used biomass feedstock, and there is potential to scale up bioenergy production using these sources,with further opportunities for scale-up from dedicated crops on degraded, surplus and marginal land. Then continue to the sentence about challenges assessing potential for bioenergy.	Accepted. sentence order changed	Government of Canada	Environment and Climate Change Canada	Canada
1085	40	21	40	21	Change "deforestation" to "land use change" because the issues are broader than just deforestation	Accepted. Changed to "land-use change, including deforestation "	Reid Miner	Private Consultant	United States of America
79635	40	21			suppress services in ecosystem services, because the question is the function of the ecosystem and not the service ecosystem gives to human societies.	Accepted. Services removed.	Marc Daras	CentraleSupelecAlumni	France
43177	40	23	41	14	This section refers to energy made with organic waste but it fails to refer to Anaerobic Digestion which is a very reliable source of energy. References to Anaerobic Digestion should be added, such as Barton, J. R., Issaias, I., & Stentiford, E. I. (2008). Carbon – Making the right choice for waste management in developing countries. Waste Management, 28(4), 690–698. https://doi.org/10.1016/j.wasman.2007.09.033 Morris, J., Scott Matthews, H., & Morawski, C. (2013). Review and meta-analysis of 82 studies on end-of-life management methods for source separated organics. Waste Management, 33(3), 545–551. https://doi.org/10.1016/j.wasman.2012.08.004	Agreed, one of the references suggested has been added.	Mariel Vilella	Zero Waste Europe/University of Manchester	United Kingdom (of Great Britain and Northern Ireland)
1031	40			44	Why BECCS is not feasible for commerical usage? Where the hurdles lie ? Effecof BECCS on deep ocean? Effect on food prices, human displacment, biodiversity, soil carbon, soil nitrogen, etc? Is it feasible to use the captured CO2 for EOR? If no, how could it be made compatible? discuss about carbon farming (pros n cons). What about DAC+U? it is more benficial rather than applying carbon capturing tech.. at the point source	Taken into account. Very broad questions that are partially answered in the literature (hence the generally high uncertainty in this space)	Alok Dhaundiyal	Szent Istvan University	Hungary
7831	40		40		There should be some explanation on Figure 6.14 itself. Also there is no explanation on abbreviations such as SCS, DME etc. In addition, though title of this figure is named as "Costs and potential for different CO2 UTILIZATION pathsay", BECCS is included here. I don't think BECCS has no relationship with CO2 utilization. BECCS is completely different from EOR, the latter of which uses CO2 for enhanced oil recovery (reutilization).	Not bioenergy section.	Mitsutsune Yamaguchi	Research Institute for the Innovative Technology for the Earth (RITE)	Japan

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
25025	40				3rd generation biofuel from Algae is an important resource moving forward	Taken into account. Possibly, algae are listed explicitly in Figure 6.15	Bassam AbuHijleh	The British University in Dubai	United Arab Emirates
52195	41	3	41	6	Very long sentence.	Accepted. Thanks, rephrased	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
63649	41	4	41	4	"bioenergy" should be replaced with "biomass"	Agreed, corrected	Government of Canada	Environment and Climate Change Canada	Canada
1029	41	5			what is CDR? Mention somewhere in text	Acronym defined	Alok Dhaundiyal	Szent Istvan University	Hungary
43179	41	10	41	14	Gasification and pyrolisis have failed in practice many times. Therefore, it is inappropiatte to deem technologies as 'notable' when they are still in the demonstration stage. Actually, gasification and pyrolysis are not only in the demonstration stage, they have failed to deliver on their promises, which is empirically contradictory with Hermwille et al 2019. Moreover, it should be added that pyrolysis and gasification are considered forms of energy recovery in the waste hierarchy according to the EU Waste Framework Directive and therefore they are at the bottom of the waste hierarchy, being the second least environmentally desirable option. References: Tangri, N., & Wilson, M. (2017). Waste Gasification & Pyrolysis: High Risk, Low Yield Processes for Waste Management. GAIA.	Accepted. This point has been clarified: The sentecne on "prominent" technology has been removed and this sentence clarofies tech status: While potentially cost-competitive, these pathways are only in the demonstration stage	Mariel Vilella	Zero Waste Europe/University of Manchester	United Kingdom (of Great Britain and Northern Ireland)
85975	41	10	41	11	Suggest clarification: Do the authors mean Integrated Gasification Combined Cycle with CO2 capture? Gasification alone produces syngas (not heat that is needed for electricity production). The gasification process needs to be coupled with a combustion process to convert the syngas to heat.	Accepted. This sentence has been removed	Government of Australia	Department of Industry, Science, Energy and Resources	Australia
85013	41	12	41	18	H2 can be added to gasification and pyrolisis processes to upgrade biofuels and entail lower impacts	Taken into account. A sentence and ref has been added on this: hydrogen can be used to enhance biofuels output in gasification-based biorefineries	Roque Pedace	UBA.Buenos Aires University	Argentina
80333	41	14	41	17	Valuation of policies that already oblige states that have adopted them to reduce emissions, as well as broaden the view on fuel and therefore energy production through biofuels.	I don't understand the comment.	JUAN DIAZ	Association	United States of America
79637	41	15			Biodisesel has been omitted, it represent 1/4 to 1/3 of all liquid biofuels. A sentence after gasoline could be " similarly, vegetable oil and animal grease based biofuel are in used, while blending methyl ester with diesel." and in the following sentence "this" becomes "these"	Agreed, corrected: Biodiesel produced from vegetable oils and animal fats and sugar-based biofuels (e.g., ethanol produced via fermentation and blended in gasoline) are currently produced in several countries	Marc Daras	CentraleSupelecAlumni	France
43181	41	18	41	21	Anaerobic digestion has been successfully employed at small scales to produce usable methane gas and animal feed. More attention should be devoted to this option given its potential to deal with organic waste. See reference: Wilson, D. C., & Velis, C. A. (2015). Waste management–still a global challenge in the 21st century: An evidence-based call for action.	Agreed but the suggested reference doesn't seem to provide any insight on anaerobic digestion. The sentence has been edited and two refs added.	Mariel Vilella	Zero Waste Europe/University of Manchester	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
79639	41	19			"RNG, and renewable natural gas" Natural gas is a mixture of methane and other gases such as ethane, oxygen, HAP… depnding of the source. Biogas production from high moisture waste gives a different mixture (methane, carbone dioxyde, oxygen...)which should be purified and adjusted if used as natural gas in the grid. Therefore, in europe at list the words biogas, biomethane, are used in order to avoid confusion. Having worked for years in this field I am suprised of this terminology.	Rejected. US Epa uses RNG: https://www.epa.gov/lmop/renewable-natural-gas but agreed, sentence rephrased: Finally, anaerobic digestion of wastes such as dairy manure, wastewater sludge and organic MSW can produce biogas that can be upgraded for use in place of fossil natural gas while also mitigating waste-related issues and emissions [REF].	Marc Daras	CentraleSupelecAlumni	France
1087	41	21	41	22	Change "saw mill residue" to "manufacturing residue" because residues are also produced by other types of manufacturing operations - e.g., bark from pulp mills	Accepted	Reid Miner	Private Consultant	United States of America
55693	41	21	41	25	In Figure 6.15, as this is supposed to represent the "range of bioenergy conversion pathways based on feedstock, targeted end product, and compatibility with CDR via CCUS and soil carbon sequestration" a major omission is food crops. In the U.S., for example, most liquid fuels are made from corn. This reality of bioenergy/biofuels is acknowledged on the next page but should not be ignored or glossed over here. Authors can reframe this to include only non-food pathways or another framing to note this omission or call a spade a spade and include all feasible and current pathways.	Taken into account. Fixed in the caption	Government of United States of America	U.S. Department of State	United States of America
9901	41	22			Suggestion: It can be added that the end-product of the biogas utilization is hydrogen. The circle symbol can be added in the figure above. (Helton José Alves and et al, Overview of hydrogen production technologies from biogasand the applications in fuel cells, International Journal of Hydrogen Energy, Volume 38, Issue 13, 1 May 2013, Pages 5215-5225)	Adressed	Government of Indonesia	Ministry of Environment and Forestry	Indonesia
47655	41	22	41	24	Figure 6.15 does not include the most prominent (by far) current uses of bioenergy: First generation biofuels & combustion for heat. Presumably the authors are focusing on advanced bioenergy, but that must be made clear.	clarified	Vassilis Daioglou	Utrecht University	Netherlands
43183	41	23	41	24	The figure is about bioenergy but it includes dry waste. In the context of municipal solid waste, dry waste could include an heterogeneous mix, including plastic, paper, metals, etc. It should therefore not be included here, as it is misleading.	Rejected. But some solid MSW could also include bio-based products	Mariel Vilella	Zero Waste Europe/University of Manchester	United Kingdom (of Great Britain and Northern Ireland)
18233	41	25	44	36	(Section 6.4.2.6) This section on bioenergy needs more in-depth discussion of the ecosystem risks associated with BECCS and the ongoing controversy surrounding BECCS carbon accounting. For example, whether or not BECCS can (or should) be counted as zero or negative emissions is still contested and especially in terms of how the carbon emissions associated with land use (and associated ecosystem service loss) and bioenergy production are calculated. There is insufficient reference in Section 6.4.2.6 to levels of evidence/confidence/agreement and to the ongoing scientific debate around BECCS, which makes it potentially misleading.	This has been clarified: There exists a high potential for carbon dioxide removal (CDR) through BECCS, but issues and concerns around its sustainability, impact on national security, land and water competition with food, biodiversity, and scale-up potential will influence the viability of BECCS (high confidence)	Government of United Kingdom (of Great Britain and Northern Ireland)	Department for Business, Energy & Industrial Strategy	United Kingdom (of Great Britain and Northern Ireland)
47661	41	25	42	4	Chapter 7, section 7.4.4 provides a review of the latest methodologies and estimates of BECCS. Perhaps it is good to link to that section to help readers get a more "in depth" assessment there.	Added, thanks	Vassilis Daioglou	Utrecht University	Netherlands

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
80633	41	25	41	29	BECCS is not carbon neutral or negative in the near-term—with a carbon deficit for many years, generally several decades to a century. Danielle Venton, Core Concept: Can bioenergy with carbon capture and storage make an impact?, PNAS (2016); Leturcq, P. (2020) GHG Displacement Factors of Harvested Wood Products: the Myth of Substitution, Nature Scientific Reports 10:1–9; Mary S. Booth, Not carbon neutral: Assessing the net emissions impact of residues burned for bioenergy, Environ. Res. Lett. 13 (21 February 2018); Sterman J. D., et al. (2018) Does replacing coal with wood lower CO2 emissions? Dynamic lifecycle analysis of wood bioenergy, Envtl. Research Letters 13(015007):1–10, 1 ("We simulate substitution of wood for coal in power generation, estimating the parameters governing NPP and other fluxes using data for forests in the eastern US and using published estimates for supply chain emissions. Because combustion and processing efficiencies for wood are less than coal, the immediate impact of substituting wood for coal is an increase in atmospheric CO2 relative to coal. The payback time for this carbon debt ranges from 44–104 years after clear-cut, depending on forest type—assuming the land remains forest. Surprisingly, replanting hardwood forests with fast-growing pine plantations raises the CO2 impact of wood because the equilibrium carbon density of plantations is lower than natural forests. Further, projected growth in wood harvest for bioenergy would increase atmospheric CO2 for at least a century because new carbon debt continuously exceeds NPP. Assuming biofuels are carbon neutral may worsen irreversible impacts of climate change before benefits accrue. Instead, explicit dynamic models should be used to assess the climate impacts of biofuels."). Furthermore, even if BECCS were net zero or negative in the relevant next couple of decades, which it is not, large-scale biodiversity development requires vast land-use changes, which may have significant implications for food security and biodiversity. National Academies of Sciences, Engineering, and Medicine, Negative Emissions Technologies and Reliable Sequestration: A Research Agenda,10 (2019) ("Because food demand is expected to double by mid-century, repurposing a significant amount	Taken into account. A lot of these concerns on BECCS have been incorporated and some of the suggested references added.	Durwood Zaelke	Institute for Governance & Sustainable Development	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
80777	41	25	41	29	BECCS is not carbon neutral or negative in the near-term—with a carbon deficit for many years, generally several decades to a century. Danielle Venton, Core Concept: Can bioenergy with carbon capture and storage make an impact?, PNAS (2016); Leturcq, P. (2020) GHG Displacement Factors of Harvested Wood Products: the Myth of Substitution, Nature Scientific Reports 10:1–9; Mary S. Booth, Not carbon neutral: Assessing the net emissions impact of residues burned for bioenergy, Environ. Res. Lett. 13 (21 February 2018); Sterman J. D., et al. (2018) Does replacing coal with wood lower CO2 emissions? Dynamic lifecycle analysis of wood bioenergy, Envtl. Research Letters 13(015007):1–10, 1 ("We simulate substitution of wood for coal in power generation, estimating the parameters governing NPP and other fluxes using data for forests in the eastern US and using published estimates for supply chain emissions. Because combustion and processing efficiencies for wood are less than coal, the immediate impact of substituting wood for coal is an increase in atmospheric CO2 relative to coal. The payback time for this carbon debt ranges from 44–104 years after clear-cut, depending on forest type—assuming the land remains forest. Surprisingly, replanting hardwood forests with fast-growing pine plantations raises the CO2 impact of wood because the equilibrium carbon density of plantations is lower than natural forests. Further, projected growth in wood harvest for bioenergy would increase atmospheric CO2 for at least a century because new carbon debt continuously exceeds NPP. Assuming biofuels are carbon neutral may worsen irreversible impacts of climate change before benefits accrue. Instead, explicit dynamic models should be used to assess the climate impacts of biofuels."). Furthermore, even if BECCS were net zero or negative in the relevant next couple of decades, which it is not, large-scale biodiversity development requires vast land-use changes, which may have significant implications for food security and biodiversity. National Academies of Sciences, Engineering, and Medicine, Negative Emissions Technologies and Reliable Sequestration: A Research Agenda,10 (2019) ("Because food demand is expected to double by mid-century, repurposing a significant amount	See response to comment #80633	Gabrielle Dreyfus	Institute for Governance & Sustainable Development	United States of America
47657	41	27	41	28	There is a forthcoming review from Roe et al. which expands on the reviews of Smith et al and Fuss et al. Roe et al. (forthcoming) Land-based measures to mitigate climate change: potential and feasibility by country, Global Change Biology	Accepted. Thanks, added	Vassilis Daioglou	Utrecht University	Netherlands
52197	41	28	41	28	"issues with biomass" is vague; what issues?	Taken into account. clarified: issues and concerns around its sustainability and scale-up will influence the viability of BECCS	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
1033	41			44	Are you sure 'gasification is considerably more flexible in terms of the feedstock that could be utilised'? Can you gasify loose biomass in wood gasfier? How will you incooperate CCS with a gasifier? The best way is to carry out WGSR (use steam here from boiler) + methanisation (remove water at the end).	Accepted. Sentence removed	Alok Dhaundiyal	Szent Istvan University	Hungary
63647	41		41		On Figure 6.15, the most prevalent uses of bioenergy are missing: combustion for industrial process heat and buildings space and water heating.	Fixed in the caption	Government of Canada	Environment and Climate Change Canada	Canada

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
45897	42	2	42	4	Please refer to the more detailed discussion on biochar in chapter 7 to enable the reader to get a complete picture of the potentials and risks of biochar application.	Taken into account. Added a ref to Chapter 7	Government of Germany	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety International Climate Policy	Germany
85015	42	2	42	7	H2 from electrolysis will help second and third generation biofuels to deliver affordable high quality synthetic fuels.	Taken into account. Sentence added: Use of carbon-free hydrogen reduces life-cycle emisisons	Roque Pedace	UBA.Buenos Aires University	Argentina
45899	42	5	42	20	Please re-assess in a more balanced way. Sustainability of so called 2nd generation biofuels may include similar risks as first generation feedstock. Comment: The promise of viable pathways to produce these fuels from secondary feedstocks remains unredeemed since a long time. What also remains since about two decades is relativizing severe sustainability gaps in first generation biofuel production by this promise of a better second generation. REFERENCE: C Malins (2017) Waste Not, Want Not: Understanding the greenhouse gas implications of diverting waste and residual materials to biofuel production; Cerulogy: London, UK, 2017	Taken into account. This point has been clarified	Government of Germany	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety International Climate Policy	Germany
47843	42	5	42	20	Again, this text should discuss price competitiveness of 2G biofuels not only from a production cost angle, but also include the present unfairly price competition to fossil fuels (neglecting externalilities). Further, it should discuss the potential for co-optimization of biofuels with respective applications. Ethanol, for instance, is proven to increase combustion efficiency. Related research has been performed by RWTH Aachen, Germany, and the US Department of Energy.	Taken into account. This point has been clarified above.	Patrick Lamers	NREL	United States of America
48007	42	5	42	13	Although production of advanced biofuels is modest, commercialization is already a reality, particularly within the context of specific policies, such as California's LCFS, RFS and EU Renewable Energy Directive (cf. IEA Renewables 2019 Market Report). Therefore, not all advanced biofuels are at pilot stage. This excerpt should be corrected accordingly.	Repeated comment	Marcelo moreira	UNICAMP - Agroicone	Brazil
50927	42	5	42	13	Although production of advanced biofuels is modest, commercialization is already a reality, particularly within the context of specific policies, such as California's LCFS, RFS and EU Renewable Energy Directive (cf. IEA Renewables 2019 Market Report). Therefore, not all advanced biofuels are at pilot stage. In Brazil, there are indications that one of the two commercial scale second generation ethanol plants has reached enough maturity and technological readiness to become competitive with first generation ethanol without specific policy support. This excerpt should be corrected accordingly.	Accepted. "pilot stage" removed	Government of Brazil	Ministry of Foreign Affairs of Brazil	Brazil
80335	42	5	42	7	Need to produce material to clarify the conceptualization of second-generation fuels, as well as to verify the possibility of expanding this list through processes that can bring them into a sustainable policy.	Taken into account. Clarified in the revision	JUAN DIAZ	Association	United States of America
79641	42	9			Biodisel has been omitted. See comments above.	Accepted. Added in several places	Marc Daras	CentraleSupelecAlumni	France
85017	42	12	42	16	see comments 19 and 20.For the same reasons upgrading with abundant sustainable electrolytical H2 is advantageous for economy and environment.	Taken into account. Added a sentence to address: Use of carbon-free hydrogen reduces life-cycle emisisons	Roque Pedace	UBA.Buenos Aires University	Argentina

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
1035	42	13	14		'The underlying processes (such as Fischer-Tropsch) are very sensitive to impurities such as sulfur.'? Where does this sulphur impregnate with Synthetic gas n(CO +2H2) ?	Noted. Biogas is primarily composed of methane and carbon dioxide. However, it also contains trace-level impurities including sulfur compounds, ammonia, halogenated compounds, silicon compounds, and volatile organic compounds (VOCs),(5) as well as moisture, nitrogen, and oxygen (https://pubs.acs.org/doi/10.1021/acs.energyfuels.9b01778#:~:text=Biogas%20is%20primarily%20composed%20of,moisture%2C%20nitrogen%2C%20and%20oxygen.)	Alok Dhaundiyal	Szent Istvan University	Hungary
86533	42	13	42	13	Most biomass feedstocks are low sulpher. Sulpher is less of an issue than the carbon monoxide hydrogen ratio, requiring gas shift reaction which reduces yield	Noted. The language doesn't quantify importance of these elements, but there seems agreement that sulfur in an issue, if present.	raphael Slade	Imperial college	United Kingdom (of Great Britain and Northern Ireland)
1037	42	16	17		Similarly, technologies producing natural gas (e.g. digestion) tend to be less efficient than thermochemicalapproaches and often produce large amounts of CO2,' It could be composting process, but not the digestion process.	Accepted. rephrased (anaerobic digestion to produce biogas)	Alok Dhaundiyal	Szent Istvan University	Hungary
79643	42	17			In the follow up of the Fisher tropsch sentence replace "producing natural gas (digestion)" by "producing synthetic methane" or "producing syngas"	corrected	Marc Daras	CentraleSupelecAlumni	France
79645	42	19			The reference to Melara et al. Is not pertinent here. It referers to analysis of an offshore production of algae used for energy. Eventually in the following §.	Deleted	Marc Daras	CentraleSupelecAlumni	France
1363	42	21	42	21	While showing a limited implementation, BECCS is commercially available. In their 2019 report, the Global CCS Institute identified five facilities around the world actively using BECCS technologies, collectively capturing c. 1.5 million tonnes per year, plus three more in different stages of development. I agree that the penetration of this technology is limited, but the statement "BECCS is not commercially available" is not right. See "Consoli, Christopher. "Bioenergy and carbon capture and storage." Global CCS Institute (2019)" https://www.globalccsinstitute.com/wp-content/uploads/2020/04/BIOENERGY-AND-CARBON-CAPTURE-AND-STORAGE_Perspective_New-Template.pdf"	Rejected. 5 pilot projects don't make BECCS commercial	Juan Alcalde	Geosciences Barcelona, CSIC	Spain
29407	42	21	42	24	(1) Please provide reference on why there is limited CO2 capture technologies for high-moisture biomass, (2) difine what is "high-moisture" in this context (algae? But algae help to take up CO2 if properly done)	Rephrased (anaerobic digestion to produce biogas)	Singfoong Cheah	Independent consultant, formerly more than 10 years with the National Renewable Energy Laboratory, USA	United States of America
29429	42	21	42	33	Consider adding information that BECCS has a potential to be combined with other form of biogenic processes already in use. CCS could be added on to biofuel production, often have high concentration of CO2 suited for CCS, resulting in biofuel with negative CO2 footprint. Another example is the waste to energy (WtE) with typical 50% biogenic waste. CCS on WtE would be an example of BECCS with no effect of land use or other effect since the biogenic materials is already in established marked streams.	Rejected. We think this point is already clear	Government of Norway	Norwegian Environment Agency	Norway

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
45901	42	21	42	33	One point missing here: Competition between BECCS and sectors for bioenergy use which aren't compatible with CC & S but could by themselves use all the worlds biomass without reaching demand at all. This is true for the transport sector as well as for many other traditional and modern bioenergy applications. Please reconsider. REFERENCE: Fajardy et al (2017); BECCS deployment: a reality check; Grantham Institute, Briefing paper No 28, Imperial College London	I don't follow this comment, sorry	Government of Germany	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety International Climate Policy	Germany
55695	42	23	42	23	Change "CO2 sinks" to "geologic sinks for CO2". For AFOLU, CO2 sink is slightly different than conveyed here.	Changed	Government of United States of America	U.S. Department of State	United States of America
29409	42	24	42	28	This sentence does not make sense. The first part talked about tradeoff..(which is fine) then it went to "energy rate of investment" then it talked about "commercial threshold" (of what?). Please restructure to tie the differnet concepts together.	Accepted. Sentence restructured	Singfoong Cheah	Independent consultant, formerly more than 10 years with the National Renewable Energy Laboratory, USA	United States of America
29411	42	30	42	33	The last sentence that spells out the challenges of doing both bioenergy and carbon storage is an important sentence and probably should be in a separate paragraph. (All the sentences before this in this paragraph are relevant to bioenergy or bioenergy with carbon capture, without the important storage part).	Editorial. Noted	Singfoong Cheah	Independent consultant, formerly more than 10 years with the National Renewable Energy Laboratory, USA	United States of America
47845	42	34	42	36	Misleading sentence that covers too much in one and has a mixed and false message. Yes, biofuel production might have impacts on land use, water use, etc. - but not all feedstock are land-based/derived. Further, biofuels such as ethanol have been blended into petroleum fuels to achieve air quality benefits related to tailpipe emissions. However, during the production phase of 2G biofuels, some process design configuration can also lead to large emissions of criteria air pollutants.	Accepted. Text Modified	Patrick Lamers	NREL	United States of America
29413	42	36	43	3	Please clarify whether the GHG implication of bienergy accounts for the energy use in water (pumping and treatment, if necessary).	Noted. While this is an interesting discussion, we cannot explore it here due to space constraints.	Singfoong Cheah	Independent consultant, formerly more than 10 years with the National Renewable Energy Laboratory, USA	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
45903	42	36	42	38	At this level of assessment, bioenergy should be analysed as a part of the global agriculture and forestry production chain and as such takes its share on environmental burden of these widely non-sustainably sectors. As such the environmental impact of bioenergy is represented (as a minimum) by its share in the impacts of global agricultural and forestry operations. Attribution of impacts to the deployment of bioenergy can be done as documented by the Global Bioenergy Partnership (GBEP; see Giegrich et al 2019, Attribution of impacts to bioenergy production and use for the implementation of the GBEP Sustainability Indicators for Bioenergy (GSI)_http://www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/Implementation_Guide/Attribution_paper_-_Final_Draft_26-March-2019.pdf) Hence, feasibility of attribution doesn't seem as uncertain as this sentence suggests. Please revise.	Noted. This discussion is carried out in detail by Chapter 7 and 12	Government of Germany	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety International Climate Policy	Germany
37687	42	38	42	49	In addition to land use, it will be appropriate to write about water requirements and the stress it might cause. (Please see Stenzel, F., Greve, P., Lucht, W., Tramberend, S. , Wada, Y. , & Gerten, D. (2021). Irrigation of biomass plantations may globally increase water stress more than climate change. Nature Communications 12 (1) e1512. 10.1038/s41467-021-21640-3.)	Accepted. Text Modified	Ravi B Grover	Homi Bhabha National Institute	India
61791	42	38	42	40	"At scales consistent with energy transitions discussed later in this chapter (Section 6.7), bioenergy is likely to exert very high stress on land use, which might be difficult to reconcile with planetary boundaries." In this light, the Illustrative Pathway scenarios in Fig. 3.14, specifically 1.5-Sup and 1.5-NBZ, appear to be in conflict as biomass constitutes up to 1/3rd of the total primary energy use in 2100. This inconsistency needs to be resolved and the IP scenarios need to be consistent with SDGs.	Rejected. Modifying the Illustrative Pathways is beyond the scope of this section	Rauli Partanen	Think Atom	Finland
65823	42	38	42	40	"At scales consistent with energy transitions discussed later in this chapter (Section 6.7), bioenergy is likely to exert very high stress on land use, which might be difficult to reconcile with planetary boundaries." In this light, the Illustrative Pathway scenarios in Fig. 3.14, specifically 1.5-Sup and 1.5-NBZ, appear somewhat surprising as biomass would constitute a major part of the energy mix in 2100, accounting for a whopping 1/3rd of the total primary energy use. Can you comment on this discrepancy between the chosen Illustrated Pathways and the anticipated sustainability limits on the use of biomass? Are the measures in (Henry et al., 2018) sufficient to alleviate the concerns? If not, then the IP scenarios should be changed to be consistent with the SDGs.	Rejected. Modifying the Illustrative Pathways is beyond the scope of this section	Eero Hirvijoki	Aalto University	Finland
1089	42	40	42	40	the term "planetary boundaries" has a specific meaning not familiar to the non-specialist. I suggest using a different term or providing a footnote with a definition.	Accepted. Text Modified	Reid Miner	Private Consultant	United States of America
45905	42	40	42	46	Please reformulate in a more balanced and less policy prescriptive manner (including replacing "will require"). The current text seems to promote ideas of technological fixes that have been criticized to lead to misguided global agricultural and forestry management systems (including the over-use of nitrogen fertilizers) which are at odds with many sustainable development goals.	Accepted. Text Modified	Government of Germany	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety International Climate Policy	Germany
85019	42	44	43	45	residues are key for increasing carbon uptake from carbon cycle both for removal, ie soil sink, and for biofuels with H2	Noted. While this is an interesting discussion, we cannot explore it here due to space constraints.	Roque Pedace	UBA.Buenos Aires University	Argentina

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
45907	42	47	43	17	Although the chapter and this paragraph already discusses many sustainability aspects of BECCS, a more detailed and critical assessment and an overview of the potentials and risks of specific upstream sources of biomass would be helpful for the reader (energy crops, by-products etc.). Furthermore it would be helpful to reference the chapter 7 to get a more detailed impression of the AFOLU component of BECCS (e.g. Section 6.4, Chapter 7).	Noted. This discussion is carried out in detail by Chapter 12	Government of Germany	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety International Climate Policy	Germany
63651	42	47	43	17	There is a lot of emphasis in this paragraph, and through the section, on the negative impacts of large scale bioenergy but almost nothing on the potential for, and demonstrated, positive impacts of bioenergy when it is sustainably sourced and implemented locally. The contribution of biomass supply for bioenergy to SDGs is analyzed in detail in: Blair, M. J.; Gagnon, Bruno; Klain, Andrew; Kulišić, Biljana. 2021. "Contribution of Biomass Supply Chains for Bioenergy to Sustainable Development Goals" Land 10, no. 2: 181. https://doi.org/10.3390/land10020181	Noted. While this is an interesting discussion, we cannot explore it here due to space constraints.	Government of Canada	Environment and Climate Change Canada	Canada
84327	42	47	43	5	Please provide an order of magnitude for the time-scale to achieve CO2 neutrality (especially regarding the horizon of the energy transition).	Noted. While this is an interesting discussion, we cannot explore it here due to space constraints.	Vincent MAZAURIC	Schneider Electric	France
37689	43	3	43	4	Likely failure to deliver zero carbon emission is an important observation. It should be included upfront in the report, else it will lie embeded here and noone will get this important information.	Noted. While this is an interesting discussion, we cannot explore it here due to space constraints.	Ravi B Grover	Homi Bhabha National Institute	India
45909	43	3	43	5	Please change "may fail" into "are likely to fail". This seems to understate some important results of analysis in climate impacts of widely used bioenergy pathways. For the EU biofuel mandates, for instance, it was shown that large parts of these mandates don't deliver ANY emission savings at all and even cause more emissions compared to a fossil baseline. REFERENCE: Valin, H. , Peters, D., van den Berg, M., Frank, S. , Havlik, P. , Forsell, N., Hamelinck, C., Pirker, J., et al. (2015). The land use change impact of biofuels consumed in the EU: Quantification of area and greenhouse gas impacts. ECOFYS Netherlands B.V. , Utrecht, Netherlands. BIENL13120.	Rejected. The text here is based on our synthesis of the literature.	Government of Germany	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety International Climate Policy	Germany
55697	43	3	43	5	Suggest rephrasing 'indirect GHG emissions' here as the referenced emissions on page 5, lines 34-36, refer to those as 'direct combustion' emissions. However, many of them are or can be direct consequences of biomass use for energy. Suggest using 'the broader environmental GHG emissions discussed above'. This will help alleviate confusion with indirect LUC which is another specific term often used in the context of bioenergy and its effects (as seen in this paragraph a few sentences after this one).	Accepted. Text Modified	Government of United States of America	U.S. Department of State	United States of America
64179	43	3	43	4	This is a strong statement to make. Is this consistent with our overall AR6 message? For e.g. would we elevate this to the ES/Technical summary? Might be good to give some more detail from the underlying references- on scale, scenario etc	Accepted. Text Modified	Minal Pathak	WGIII TSU, Ahmedabad University	India
47847	43	4	43	4	discussed above'? Where? Earlier statements are incomplete and misleading. The potentila indirect GHG emissions from biomass should be specifically discussed or a discussion refered to other chapters of the AR6.	Accepted. Reference has been made to chapter 12	Patrick Lamers	NREL	United States of America
1039	43	5			discuss this 'upstream burdens'	Noted. While this is an interesting discussion, we cannot explore it here due to space constraints.	Alok Dhaundiyal	Szent Istvan University	Hungary

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
47659	43	6	43	9	The following references highlight the point appropriately (even better than the cited papers): https://www.nature.com/articles/s41558-017-0006-8 https://www.nature.com/articles/s41558-020-0885-y https://www.nature.com/articles/nclimate2642	Accepted. These papers have been cited in the text.	Vassilis Daioglou	Utrecht University	Netherlands
55699	43	16	43	17	Does this chapter define 'dedicated energy' to include corn and other crops and wood (like pulpwood)? Typically dedicated energy crops are things like switchgrass and miscanthus, so the application of dedicated energy here to corn (in either situation in parentheses) is confusing. Be sure to define this term early in the chapter as it has been used a lot throughout and might mean different things to different readers/communities.	Noted. While this is an interesting discussion, we cannot explore it here due to space constraints.	Government of United States of America	U.S. Department of State	United States of America
79647	43	17			unclear parenthesis)	Rejected. Comment unclear	Marc Daras	CentraleSupelecAlumni	France
79649	43	18	43	19	this § seems to be dedicated to liquid fuel. The second sentence refers to waste, which is not a ressource for liquid biofuels presently.Finaly biodiesel is once again omitted. § to be clarified.	Rejected. Comment unclear	Marc Daras	CentraleSupelecAlumni	France
47663	43	19	43	21	Not sure the Hanssen et al (2020) reference is appropriate. That is a comparison of 8 IAMs concerning how the model supply and use of residues in climate change mitigation pathways. The paper does not do any original research on the current use of residues.	Accepted. Different reference has been provided.	Vassilis Daioglou	Utrecht University	Netherlands
55701	43	20	43	21	The preceding sentence focuses on sugar-based resources and this one, seeming to build on last, references only 'waste'. What is the definition of 'waste' here and throughout the chapter? Again, different terms mean different things to different readers/communities.	Noted. While this is an interesting discussion, we cannot explore it here due to space constraints.	Government of United States of America	U.S. Department of State	United States of America
1091	43	28	43	30	Please check the numbers in the table. In several cases they indicate that bioelectricity production is cheaper with CCS than it is without CCS.	Rejected. The general range of electricity with CCS is costlier than without CCS.	Reid Miner	Private Consultant	United States of America
45491	43	28	43	30	The cost penalties for applying CCS are vey low. Typically 1-10 USD/MWh = 0.1-1 cent/kWh. Can this really be true?	Noted. This is based on the EMF-33 paper.	Kornelis Blok	Delft University of Technology	Netherlands
47665	43	28	43	30	This table is very useful and I appreciate its inclusion. The Daioglou et al. (2020) data shows projections of costs across 2020-2100. What timestep was used to determine these numbers.	Accepted. This was based on 2020 costs.	Vassilis Daioglou	Utrecht University	Netherlands
1041	43	34		38	discuss 'biofuelyield per hectare' 'plantation area', and 'productive years'. Add information about bio diesel obtained from Jatropa.	Noted. While this is an interesting discussion, we cannot explore it here due to space constraints.	Alok Dhaundiyal	Szent Istvan University	Hungary
63655	43	34	44	12	Thermal energy (heat) should be included as a bullet point in the cost section. Biomass heat is cost competietive, and often lower cost than fuel oil, electric or propane heating, and only slightly more than natural gas in many jurisdictions. Technology is commercial and efficient (up to >90% for CHP) and proven.	Noted. While this is an interesting discussion, we cannot explore it here due to space constraints.	Government of Canada	Environment and Climate Change Canada	Canada
79651	43	36			the sentence is unclear: does CCS refer to the production of liquid biofiuels for electricity production, or to theuse of the liquid biofuel in electricity production?	Taken into account. The sentence applies to liquid biofuels and is accordingly within that bullet.	Marc Daras	CentraleSupelecAlumni	France
55703	43	37	43	38	Sentence refers to technological learning twice.	Accepted. Text Modified	Government of United States of America	U.S. Department of State	United States of America
64133	43	37	43	38	The sentence "It is projected that technological learning could reduce these costs by half resulting from technological learning (IEA 2020e)." needs rephrasing to avoid repetition. i.e., "It is projected that technological learning could reduce these costs by half (IEA 2020e)."	Accepted. Text Modified	Ghulam Rasul Athar	Pakistan Atomic Energy Commission	Pakistan
85021	43	37	43	38	technological learning should be incentivised in order to decrease costs of advanced biorefineries and synthesis with H2. see comments 19 to 22.	Noted. While this is an interesting discussion, we cannot explore it here due to space constraints.	Roque Pedace	UBA.Buenos Aires University	Argentina

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
63653	43		43		In Table 6.3, prices per MWh for bio-electricity, hydrogen and liquid fuels should be compared to a baseline price for each type of energy from fossil sources. This table is also missing the cost of biomass thermal energy (i.e. for district heating) or combined heat and power, which are the most efficient and lowest cost ways to convert biomass to energy	Taken into account. The baseline may be found in the costs and potential section.	Government of Canada	Environment and Climate Change Canada	Canada
55705	44	1	44	7	Recommend that electrolysis costs being used in this comparison are consistent with electrolysis costs elsewhere in report.	Accepted. Text Modified	Government of United States of America	U.S. Department of State	United States of America
61793	44	1	44	7	It is mentioned that hydrogen production from biomass is "(by 50-200%) cheaper than hydrogen produced from electrolysis utilising solar/wind resources." The cited resource (Kayfeci et al., 2019, https://doi.org/10.1016/B978-0-12-814853-2.00003-5) lists hydrogen also from nuclear at much lower cost than from solar of wind. This information needs to be communicated in section 6.4.2.4 and in Figure 6.1.	Noted. This is beyond the scope of this section.	Rauli Partanen	Think Atom	Finland
64135	44	1	44	1	higher than ? . Need to compare or rephrasing sentence	Rejected. The next part of the sentence already discusses this.	Ghulam Rasul Athar	Pakistan Atomic Energy Commission	Pakistan
65825	44	1	44	7	It is mentioned that hydrogen production from biomass is "(by 50-200%) cheaper than hydrogen produced from electrolysis utilising solar/wind resources." The cited resource (Kayfeci et al., 2019, https://doi.org/10.1016/B978-0-12-814853-2.00003-5) lists hydrogen also from nuclear at much lower cost than from solar of wind. Why is this information not communicated in the section 6.4.2.4 and in Figure 6.1? Revise accordingly.	Noted. This is beyond the scope of this section.	Eero Hirvijoki	Aalto University	Finland
69531	44	1	44	7	Hydrogen produced from electrolysis using solar/wind resource may have costs at USD2/kg in best areas today (the time to build them), which is approximatively the cost of blue hydrogen. See Philibert C., 2017 Renewable Energy for Industry, IEA Insights Paper; IEA, 2019, The Future of Hydrogen; Armijo, J. andC. Phiibert, 2020, Flexible production of green hydrogen and ammonia from variable solar and wind energy: Case study of Chile and Argentina, Int. J. Hydrog Energy 45, 3, 1541-1558.45, 3, 1541-1558.	Noted. This is beyond the scope of this section.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
69533	44	1	44	7	It would be interesting to question here the value of extracting hydrogen from biomass. There will likely be a need of hydrocarbons in the future, for chemical industries and for aviation notably. To have lowest possible LCA GHG emissions, these HC could be biofuels/biofeedstocks, or synthetised from green hydrogen and carbon from biomass. Studies have shown that it's possible to deliver 2 to 4 times more sustainable fuels and feedstocks from biomass by adding hydrogen to it, rather than subtracting it. See, e.g. Hannula I. 2016, Hydrogen enhancement otential of synthetic biofues manufacture in the European context: A techno-economic assessment, Energy, vol. 104, 199-212; Albrecht et alii, 2017 A standardized methodology for the techno-economic evaluation of alternative fuels - a case study, Fuel, 194: 511-526	Noted. While this is an interesting discussion, we cannot explore it here due to space constraints.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
7863	44	5	44	5	resource (close to 500,000 EJ). Oil and gas resources are an order of magnitude smaller (15-20 EJ each) -- the values above need checked - they are more than an order of magnitude apart	Accepted. Text Modified	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
85023	44	5	44	7	H2 will be cheaper than sustainable biofuels, hence it will be used to make the most of carbon uptake.see comments18 to 23.see NREL report 2020 for costs of H2 by SOEC and by biorefineries	Noted. While this is an interesting discussion, we cannot explore it here due to space constraints.	Roque Pedace	UBA.Buenos Aires University	Argentina

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
55707	44	6	44	7	Recommend adding a statement about geologic limitations of CCS (requirement for specific geologies and available land).	Accepted. Text Modified	Government of United States of America	U.S. Department of State	United States of America
69527	44	6	44	6	"by 50 - 200% cheaper" means nothing. More exactly, 50% cheaper means "half the price", but 200% cheaper is non-sense.If you meant "electrolysis is 50% to 200% more expensive", this could be expressed with by "33 to 66% cheaper"	Accepted. Text Modified	Cédric PHILIBERT	Institut Français des Relations Internationales	France
11673	44	7	44	7	Besides the economical aspect in the case of hydrogen, the obstacle to its application in same cases is due to the lack of appropriate local codes and constrains that makes difficult these kind of installations.	Noted. While this is an interesting discussion, we cannot explore it here due to space constraints.	CHIARA PUGNALINI	Altran Italy (Energy, Industry, Life Science division), European Commission	Italy
69529	44	7	44	7	Newborough and Cooley 2020 does not figure in the reference list.	Accepted. Reference list will be modified.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
80635	44	8	44	12	The cost consideration of BECCS should be made after addressing the fundamental carbon accounting issue of bioenergy. Particularly, BECCS is complicated by the fact that it is not carbon neutral in the near-term—with a carbon deficit for many years, generally several decades to a century—that is crucial for mitigating emissions and avoiding hitting the 1.5°C mark. Danielle Venton, Core Concept: Can bioenergy with carbon capture and storage make an impact?, PNAS (2016); Leturcq, P. (2020) GHG Displacement Factors of Harvested Wood Products: the Myth of Substitution, Nature Scientific Reports 10:1–9; Mary S. Booth, Not carbon neutral: Assessing the net emissions impact of residues burned for bioenergy, Environ. Res. Lett. 13 (21 February 2018); Sterman J. D., et al. (2018) Does replacing coal with wood lower CO2 emissions? Dynamic lifecycle analysis of wood bioenergy, Envtl. Research Letters 13(015007):1–10, 1 ("We simulate substitution of wood for coal in power generation, estimating the parameters governing NPP and other fluxes using data for forests in the eastern US and using published estimates for supply chain emissions. Because combustion and processing efficiencies for wood are less than coal, the immediate impact of substituting wood for coal is an increase in atmospheric CO2 relative to coal. The payback time for this carbon debt ranges from 44–104 years after clear-cut, depending on forest type—assuming the land remains forest. Surprisingly, replanting hardwood forests with fast-growing pine plantations raises the CO2 impact of wood because the equilibrium carbon density of plantations is lower than natural forests. Further, projected growth in wood harvest for bioenergy would increase atmospheric CO2 for at least a century because new carbon debt continuously exceeds NPP. Assuming biofuels are carbon neutral may worsen irreversible impacts of climate change before benefits accrue. Instead, explicit dynamic models should be used to assess the climate impacts of biofuels.").	Noted. While this is an interesting discussion, we cannot explore it here due to space constraints.	Durwood Zaelke	Institute for Governance & Sustainable Development	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
80779	44	8	44	12	The cost consideration of BECCS should be made after addressing the fundamental carbon accounting issue of bioenergy. Particularly, BECCS is complicated by the fact that it is not carbon neutral in the near-term—with a carbon deficit for many years, generally several decades to a century—that is crucial for mitigating emissions and avoiding hitting the 1.5°C mark. Danielle Venton, Core Concept: Can bioenergy with carbon capture and storage make an impact?, PNAS (2016); Leturcq, P. (2020) GHG Displacement Factors of Harvested Wood Products: the Myth of Substitution, Nature Scientific Reports 10:1–9; Mary S. Booth, Not carbon neutral: Assessing the net emissions impact of residues burned for bioenergy, Environ. Res. Lett. 13 (21 February 2018); Sterman J. D., et al. (2018) Does replacing coal with wood lower CO2 emissions? Dynamic lifecycle analysis of wood bioenergy, Envtl. Research Letters 13(015007):1–10, 1 (“We simulate substitution of wood for coal in power generation, estimating the parameters governing NPP and other fluxes using data for forests in the eastern US and using published estimates for supply chain emissions. Because combustion and processing efficiencies for wood are less than coal, the immediate impact of substituting wood for coal is an increase in atmospheric CO2 relative to coal. The payback time for this carbon debt ranges from 44–104 years after clear-cut, depending on forest type—assuming the land remains forest. Surprisingly, replanting hardwood forests with fast-growing pine plantations raises the CO2 impact of wood because the equilibrium carbon density of plantations is lower than natural forests. Further, projected growth in wood harvest for bioenergy would increase atmospheric CO2 for at least a century because new carbon debt continuously exceeds NPP. Assuming biofuels are carbon neutral may worsen irreversible impacts of climate change before benefits accrue. Instead, explicit dynamic models should be used to assess the climate impacts of biofuels.”).	Noted. While this is an interesting discussion, we cannot explore it here due to space constraints.	Gabrielle Dreyfus	Institute for Governance & Sustainable Development	United States of America
84329	44	9	44	9	Remove with CCS (obvious and therefore confusing).	Accepted. Text Modified	Vincent MAZAURIC	Schneider Electric	France
1043	44	13	14		Acceptability of biomass and biofuel is relatively low compared to other renewable low-carbon fuels like solar and wind' Where is the assertion? Without cost analysis, it is just a vague statement.	Rejected. We have provided references for the statements.	Alok Dhaundiyal	Szent Istvan University	Hungary
17369	44	13	44	13	Social aspect of biomass (wood heating) is neglected. Wood is the cheapest source of heating in Slovenia (and in many other countries). Replacing it with heat pumps and renewables is economically impossible in the next decade(s) for the less wealthier	Noted. While this is an interesting discussion, we cannot explore it here due to space constraints.	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
84331	44	13	44	14	Please provide a regional description.	Noted. While this is an interesting discussion, we cannot explore it here due to space constraints.	Vincent MAZAURIC	Schneider Electric	France
1045	44	20	21		The most important concerns about woody biomass are air pollution and loss of local forests. It depends on how the authors define woody biomass. I think it is not a correct statement.	Noted. While this is an interesting discussion, we cannot explore it here due to space constraints.	Alok Dhaundiyal	Szent Istvan University	Hungary
55709	44	20	44	21	There are other concerns with woody biomass like competition with other traditional wood products. Also, there is no mention of the most important concern of agricultural crops, especially food crops, for energy, including pressure on food production and prices and related food security and land use change. Seems important to include if pointing out concerns or why there is controversy.	Noted. While this is an interesting discussion, we cannot explore it here due to space constraints.	Government of United States of America	U.S. Department of State	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
79091	44	20	44	21	Air pollution and forest loss are two concerns, but so are losses to soil carbon stores, removal of nutrients (and subsequent reductions in productivity), and lags between carbon release and re-sequestration as forests are harvested regrow during a critical period of emissions reductions	Noted. While this is an interesting discussion, we cannot explore it here due to space constraints.	Edith Juno	National Wildlife Federation	United States of America
63167	44	21			:Loss of forests is of special concern because elimination of these carbon sinks may lessen the decarbonisation benefits of bioenergy production. (McCord, G., D. Kanter, J. Sklarew, G. Wu, and M. Jacobson. 2020. “Accelerating Sustainable Land Use Practices in the U.S.,” in America's Zero Carbon Action Plan: Roadmap to Achieving Net Zero Emissions by 2050, 262-281. New York: SDSN. https://www.unsdsn.org/Zero-Carbon-Action-Plan)	Noted. While this is an interesting discussion, we cannot explore it here due to space constraints.	Jennifer Sklarew	George Mason University	United States of America
85315	44	24	44	26	This is a key finding that should be reflected in the SPM.	Noted. While this is an important point, ES discussions are limited due to the current space constraints.	Kaisa Kosonen	Greenpeace	Finland
1093	44	26	44	26	This paragraph is missing a key finding from Chapter 7. Accordingly, a sentence should be added (after …"planetary boundaries…" saying the following: "In addition, the benefits of biomass energy are highly variable, affected by complex interaction between multiple factors and drivers, and involving a significant number and range of stakeholders. Therefore, the feasibility of biomass energy is highly context specific and high-level mitigation assessments must be used with caution."	Rejected. Our discussion here is based on our synthesis.	Reid Miner	Private Consultant	United States of America
79653	44	26			suggest instead of reconcile with planet boundaries which is a reference to a specific set, i suggest " to function contributing to the SDGs globally, both on environmental and social matters." This refers to the earlier metrics proposed.	Accepted. Text Modified	Marc Daras	CentraleSupelecAlumni	France
10933	44	28	44	28	insert "." between "and trade" and "Current biomass…"	Accepted. Text Modified	Dong-Woon NOH	Korea Energy Economics Institute	Republic of Korea
16357	44	28	44	28	insert "." between "and trade" and "Current biomass…"	Accepted. Text Modified	Government of Republic of Korea	Korea Meteorological Administration (KMA)	Republic of Korea
85025	44	30	44	32	trade routes should be different for biomass and for sustainable high quality synthetic biofuels using H2 as input.	Noted. While this is an interesting discussion, we cannot explore it here due to space constraints.	Roque Pedace	UBA.Buenos Aires University	Argentina
52199	44	35	44	35	"Several" is the wrong word in this context.	Accepted. Text Modified	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
17511	44	37	44	38	please rephrase "technological learning" twice	Accepted.	Alaa Al Khourdajie	IPCC	United Kingdom (of Great Britain and Northern Ireland)
8985	44	38	44	41	This sentence is logically flawed. The primary mechanism for reducing emissions is not “to eliminate the unabated use of fossil fuels”, but “to eliminate the use of fossil fuels”. Furthermore, it is logically incorrect to state that “the fossil energy combined with CCUS provides a means to produce low- or near-zero carbon energy”, since any source of any kind, when combined with CCUS, provides a means to produce low- or near-zero carbon energy. Furthermore, fossil fuels are the source that require more CCUS to do that.	Noted. The text is based on the messages derived from our synthesis of peer-reviewed literature	Francesco Gonella	Ca' Foscari University of Venice, Italy	Italy

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
16941	44	38	44	38	"Fossil fuels play a unique role in climate change mitigation" is a stament that sound weird to non native english speakers and could led to confussion, moreover if taken out of context.	Accepted. Text modified	Government of Spain	Area de Estrategias de Adaptacion - Oficina de Cambio Climatico - Ministerio de la Transicion Ecologica	Spain
28513	44	38	44	41	I find the opening ("Fossil fuels play a unique role in climate change mitigation.") rather weird and unnecessarily uplifting. I'd rather say that "fossil fuels play a unique role in climate change" - their combusion being largely responsible for it - and not really for "climate change mitigation". I recommend cutting the opening sentence and rephrasing as "The primary mechanism for reducing emissions is to eliminate the unabated use of fossil fuels. Nevertheless, fossil energy combined with CCUS can provide a means to produce low- or near-zero carbon energy while utilizing the available base of fossil energy worldwide. If successfully developed, this solution can help limiting stranded assets."	Accepted. Text modified	Pierpaolo Cazzola	International Transport Forum	France
43879	44	38	44	38	"Fossil fuels play a unique role in climate change mitigation." is a controversial narrative to include in public report on climate change mitigation, which should be oriented towards shifting or divesting from fossil fuel consumption, even with the use of CCUS technology. According to the 2020 Special Report "The Production Gap" [16], which is backed by the United Nations Environment Programme (UNEP), countries must cut their fossil fuel consumption at a rate of 6% per year in order to not exceed the 1.5ºC threshold set by the Paris Agreement. In reference to that, this entire section (6.4.2.7 Fossil Energy) seems to be promoting the coninuing consumption of fossil fuels. My suggestion is to present a particular fossil fuel such as natural gas and its potential to be a "transition fuel" [17] which can be used as support for renewable energy uptake as reported by UNECE [18]. Since natural gas is the least carbon intensive fossil fuel, it can have a quite unique role in climate change mitigation. I hope you consider this comment.	Accepted. Text modified	Vince Davidson Pacañot	University of the Philippines Diliman	Philippines
52275	44	38	44	41	"fossil energy combined with CCUS provides a mean to produce low- or near-zero carbon energy..." this needs to be emphasized and included in the SPM to give all possible options to decision makers.	Noted. While this is an important discussion, we cannot include it because of space constraints.	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
69535	44	38	44	38	It would rather write "Fossil fuels play a unique role in climate change" (high confidence). If you add "mitigation", this becomes entirely speculative and unproven yet at any significant scale, and is met with low confidence I'm afraid.	Accepted. Text modified	Cédric PHILIBERT	Institut Français des Relations Internationales	France
2657	44	39	44	41	Near-zero is a very strong word given the non-one efficiencies of CCS.	Accepted. Text modified	Jan Wohland	ETH Zurich	Switzerland
1047	44			46	I did not get any information about IGCC, which is related to coal and biomass gasification. Discuss importance of CDM in the coal plant.	Noted. While this is an important discussion, we cannot include it because of space constraints.	Alok Dhaundiyal	Szent Istvan University	Hungary
1049	45	1			increased	Accepted.	Alok Dhaundiyal	Szent Istvan University	Hungary
17907	45	1	45	18	there seems to be a mixing of resources and reserves throughout this paragraph	Accepted.	Robert Brecha	Climate Analytics	Germany
17905	45	3	45	8	units mixup here. 15-20 ZJ	Accepted.	Robert Brecha	Climate Analytics	Germany

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
17371	45	5	45	6	Lowering of EROI index is mentioned only in fossil fuel section. Intrinsically low EROI of solar and wind (especially with storage requirements taken into account) is ignored in solar and wind sections. Moreover, EROI of wind and solar is decreasing with increasing penetration Reference: Iñigo Capellán-Pérez et al. Dynamic Energy Return on Energy Investment (EROI) and material requirements in scenarios of global transition to renewable energies, Energy Strategy Reviews, Volume 26, 2019, 100399, ISSN 2211-467X, https://doi.org/10.1016/j.esr.2019.100399.	Noted. While this is an important discussion, we cannot include it because of space constraints.	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
61983	45	5	45	5	Major unit conversion error: change "Oil and gas resources are an order of magnitude smaller (15-20 EJ each)." to "Oil and gas resources are an order of magnitude smaller (15-20,000 EJ each)." i.e. reserves are 1000 larger than indicated. (Erroneusly indicated reserves are less than yearly production from Figure 6.1 in page 7)	Accepted.	Esa Vakkilainen	LUT University, Lappeenranta	Finland
78505	45	5	45	6	EROI index is mentioned only in fossil fuel section. Intrinsically low EROI of solar and wind (especially with storage requirements taken into account) is ignored in solar and wind sections. Moreover, EROI of wind and solar is decreasing with increasing penetration Reference: Iñigo Capellán-Pérez et al. Dynamic Energy Return on Energy Investment (EROI) and material requirements in scenarios of global transition to renewable energies, Energy Strategy Reviews, Volume 26, 2019, 100399, ISSN 2211-467X, https://doi.org/10.1016/j.esr.2019.100399.	Noted. While this is an important discussion, we cannot include it because of space constraints.	Tomaž Žagar	Faculty for Energy Technology, University of Maribor	Slovenia
80455	45	5	45	5	15-20EJ resources for each oil and gas might be a typo, please check.	Accepted.	Moritz Riede	University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
70167	45	6			Brockway et al. 2019). However when final stage ratios are taken into account, the EROI of fossil fuels appears to be much lower: around 6:1 and declining (Brockway et al, 2019). https://www.nature.com/articles/s41560-019-0425-z	Accepted.	Rayner Andersen	Department of Fisheries and Oceans	Canada
1051	45	11			comma before such	Accepted. Text modified	Alok Dhaundiyal	Szent Istvan University	Hungary
2659	45	11	45	13	How does CCU allow for continued use of fossil fuels? I understand the argument that CCS would allow to reduce carbon emissions from coal/gas power plants by ~90% thus implying that we can use more coal&gas until the carbon budgets are depleted. However, in CCU applications, carbon is typically not stored for a sufficiently long time. If CCU is used for synthetic fuels, for example, the carbon is only stored for a short timespan of a few weeks or so. Counting this kind of fossil based CCU as consistent with net zero emissions is contradictory. I would thus suggest to clarify that this sentence is only true (in a limited, not a strict sense) for CCS rather than CCU.	Taken into account. This discussion may be found in sections 6.7.3 and 6.7.4	Jan Wohland	ETH Zurich	Switzerland
69547	45	13	45	16	Not only the link to BECCS and CDR should lead to write CCS but not CCUS, as utilisation is very unlikely to ever lead to negative emissions, but the word "increase" is hard to understand. Some continued fossil use coupled with compatible with climate targets, but I have great difficulties understand how a continued increased of fossil fuel use can be compatible with climate targets.	Accepted. Text modified	Cédric PHILIBERT	Institut Français des Relations Internationales	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
69549	45	19	45	20	What does this sentence mean? 2% of the coal and 6% of the natural are already used to produce hydrogen delivered to refineries, ammonia and methanol plants and some others. New hydrogen markets would possibly open for the sake of decarbonisation, incl. for manufacturing ammonia for deep sea shipping, e-kerosene for aviation, and steel making. It is unclear if fossil fuel can play a significant role here, even in association with CCS. Coal partial oxidation with CCS is unlikely to satisfy the requirement for low-carbon hydrogen. Natural gas oxydation and reforming in auto-thermal/steam reformer might, but this remains to be seen. In the meantime, requirements for hydrogen in refineries will eventually vanish with oil products, and demand for nitrogen fertilisers may also recede due to more efficient, climate-friendly and biodiversity-friendly agriculture practices.	Noted. While this is an important discussion, we cannot include it because of space constraints.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
79655	45	21	45	24	The sentence could be: "The costs of extracting oil and gas from unconventional reservoirs have gown down by the improvment of hydraulic fracturing and directionnal drilling. While the extraction cost for these ressources is still more expensive than those of the most accessible reservoirs, the availability of unconventional oil and gas has limited oil and gas prices by competition." The cost of shale oil oil extraction in the US is estimated between 30-35 US$/bl. It is similar to less accessible traditional reservoir which are part of the normal oil market. In the above formula, I avoid to enter in the price formation which take into account geopolitical reason, and capacities of the main OPEP producer to control the price by expanding their low cost production, however with an impact on revenus as in the period 2016-2018.	Noted. While this is an important discussion, we cannot include it because of space constraints.	Marc Daras	CentraleSupelecAlumni	France
69551	45	27	45	30	Natural gas liquids are liquid hydrocarbons and therefore cannot be alternative to liquid fuels and to hydrocarbons. According to the IPCC 2006 guidelines they have a default effecitve CO2 emission factor of 64 200 kg/TJ, slightly less than most liquid oil products but more than natural gas or LPG. It is not false to say they are "lower-carbon" alternative to other liquid fuels and hydrocarbons but the reader should know the difference is a modest 7.4% reduction of carbon content compared to gasoline, and generally less than 10% reduction.	Noted. While this is an important discussion, we cannot include it because of space constraints.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
79657	45	27			by" natural gas liquid" it is meant LPG, liquified petroleum gas, I believe.	Rejected. No - the text here pertains to Natural Gas Liquids, co-derived during shale gas extraction	Marc Daras	CentraleSupelecAlumni	France
1053	45	28			increased by	Accepted. Text modified	Alok Dhaundiyal	Szent Istvan University	Hungary
55711	45	30	45	30	Recommend changing "converted to hydrogen" to "used to produce hydrogen".	Accepted. Text modified	Government of United States of America	U.S. Department of State	United States of America
10641	45	31	45	33	This may be true; however your reference Newborough and Cooley conclude their abstract by "...it appears that green hydrogen will soon be cheaper than blue hydrogen due to the falling costs of renewable electricity and electrolysers, then cheaper than grey hydrogen…" which contradicts your statement unless I am mistaken with colours! Hence, at least some explanation is necessary.	Accepted. Text modified	Philippe Waldteufel	CNRS	France
28515	45	31	45	33	The comparative advantage (in terms of costs) of blue hydrogen vs. green hydrogen depends on the cost of producing renewable electricity and load hours of electrolysers, as show here: https://www.iea.org/reports/the-future-of-hydrogen. This is a different (and more balanced, I think) message compared to the one contained in the text. I recommend revising it.	Accepted. Text modified	Pierpaolo Cazzola	International Transport Forum	France
55713	45	31	45	33	What is the price range for hydrogen production via electrolysis? This is described elsewhere in the chapter, but including the reference here will clarify what the difference in production costs is between these two options.	Accepted	Government of United States of America	U.S. Department of State	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
69539	45	31	45	33	As already mentioned, hydrogen from renewable in best areas will have a cost of around 2USD/kgH2, at worse 25% less than that of hydrogen from natural gas with CCS (USD1.5/kg H2 in the best areas in Middle East or the US - and much more volatile). One objection might be this is largely speculative and not demonstrated at scale - but exactly the same applies to hydrogen production with CCS, which exists nowhere. In integrated ammonia/urea plants process CO2 emissions are captured and use to make urea, but this leaves 35-40% of the emissions of steam methane reforming unabated... and most of the carbon in urea will eventually end up in the atmosphere after urea has been used in the fields.	Taken into account. This discussion is elsewhere in the chapter i.e. section 6.6	Cédric PHILIBERT	Institut Français des Relations Internationales	France
69541	45	31	45	33	The effectiveness in reducing emissionss will not be the same. As the text reads, there would be 90% efficacy in capturing the CO2, but you have to account for 1) the increased energy consumption needed for the capture process and 2) upstream emissions of methane. All in all, the process will likely mean 80% emission reductions, while hydrogen based on renewables will have much lower LCA emissions to take account of the manufacturing of solar and wind capacities and eletrolysers.	Refer to comment 65939	Cédric PHILIBERT	Institut Français des Relations Internationales	France
85027	45	31	45	33	H2 from fossils with CCS will have higher costs and higher carbon footprint than electrolytical H2 from renewables	Refer to comment 65939	Roque Pedace	UBA.Buenos Aires University	Argentina
1569	45	32	45	33	"the costs of this process are considerably less than hydrogen production via electrolysis and ranges around USD 1.5-2/kg-H2": This should include the price assumed for electricity in the cited study, given the very low prices likely around noon in the future.	Refer to comment 65939	Martin Green	UNSW Sydney	Australia
69537	45	33			Newborough and Cooley 2020 does not figure in the reference list.	Refer to comment 65939	Cédric PHILIBERT	Institut Français des Relations Internationales	France
45911	45	34	45	39	Please also discuss the combustion of mine gas, as it converts methane from mines into CO2 which has a lower GWP than CH4.	Accepted. Coal mine methane recpvery has already been mentioned	Government of Germany	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety International Climate Policy	Germany
45913	45	34	45	39	Please discuss that gasification of coal is not a carbon-free process because also CO is produced and cite relevant literature.	Accepted. A couple of lines have added here	Government of Germany	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety International Climate Policy	Germany
15101	45	35	45	36	China has carried out a lot of work in the field of underground coal gasification. The underground coal gasification project in Xinjiang has been in stable operation https://xj.chinadaily.com.cn/a/201908/01/WS5d423c95a3106bab40a03974.html . It is suggested that this progress be reflected in the paper.	Noted. While this is an important discussion, we cannot include it because of space constraints.	Guoquan HU	National Climate Center of China Meteorological Adminstration	China
69543	45	35	45	35	Finally fugitive methane emissions are mentioned but only when they can be reduced.	Noted. While this is an important discussion, we cannot include it because of space constraints.	Cédric PHILIBERT	Institut Français des Relations Internationales	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
1265	45	40	45	45	The sentence "The cost of producing electricity has remained roughly the same with some regional exceptions while the costs of transport fuels has gone down significantly (high confidence)" is misleading or incorrect. The market price of electricity is highly volatile. The market price of oil has gone up and down, but the costs of generating electricity and costs of recovering oil have been remarkably similar in that conventional costs have been relatively flat while new technologies have demonstrated substantial drop in cost all the while that market prices have been volatile. If one compares the change in cost of delivering solar electricity to the change of cost of delivering shale oil in the last couple of decades, one could easily conclude that electricity costs have dropped more than oil costs. Additionally, the sentence "Similarly, the global price of crude oil has declined from almost USD 100/bbl to USD 55/bbl in the last five years." This gives the impression that the price drop is a systematic development. However, the data suggest otherwise. The data suggest that the price of oil and goes up and down with global developments - The oil embargo in the 1970s caused a spike with a subsequent decrease for about two decades before rumors of "Peak oil" caused high prices in the early 2000s. With the introduction of hydraulic fracturing and lateral drilling, the U.S. increased supply and the prices fell, as noted, but as an earlier paragraph noted that costs for hydraulic fracturing are higher than conventional, it is NOT because the newer extraction techniques provide a lower cost. The increase in supply surprised the world and prices fell so much that profit margins dropped and companies went out of business. As we come out of the pandemic and associated low demand, prices could easily climb. Caution should be used in giving the impression that prices are coming down because of new technology development. The message should be that new technology has enabled recovery of substantially more oil, but the cost of that recovery is still higher than the conventional oil recovery has been. I would suggest rewriting the paragraph with a less biased spin.	Accepted. Text modified	Sarah Kurtz	University of California Merced	United States of America
64251	45	40	46	6	Great to discuss the energy return of investment (EROI) in connection with fossil fuels. Please mention also EROI in connection with nuclear energy in the appropriate section (e.g. Section 6.4.2.4 Nuclear Energy on page 34). Life-cycle analysis, focused on energy, is useful for comparing net energy yields from different methods of electricity generation. Nuclear power shows up very well as a net provider of energy, and only hydro-electricity is nearly comparable. = > Examples of EROI assessments: 3.5 for Biomass (corn) ; 28 for fossil gas in a CCGT ; 49 for Hydro (medium-sized dam) ; 75 for Nuclear (in a PWR). Source: "Energy intensities, EROIs (energy returned on invested), and energy payback times of electricity generating power plants", Weißbach D. et al, Energy, Volume 52, Pages 210-221 (April 2013) / from Institut für Festkörper-Kernphysik Berlin, Germany / (https://festkoerper-kernphysik.de/Weissbach_EROI_preprint.pdf) and website of Elsevier ScienceDirect : http://www.sciencedirect.com/science/article/pii/S0360544213000492#tbl8)	Noted. While this is an important discussion, we cannot include it because of space constraints.	Georges VAN GOETHEM	Royal Academy of Overseas Sciences (ARSOM - KAOW)	Belgium
52201	45	42	45	43	Sentence is self-contradictory: costs are static but have decreased 40%. Fix	Noted. The text mentions some key regional differences which the 40% is representative of.	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
1055	45	44			the vast	Accepted.	Alok Dhaundiyal	Szent Istvan University	Hungary
69545	45	46	45	46	This sentence delivers a very ambiguous message, but cannot be actually appreciated in the lack of explicit determination of how much gross emissions are compatible with zero net emissions. I would at least suggest deleting utilisation in that sentence, as if it may reduce emissions it is neither negative nor carbon neutral.	Accepted. Text modified	Cédric PHILIBERT	Institut Français des Relations Internationales	France
1267	45	47	46	2	The claim that "Fossil fuels create significantly larger amounts of energy per unit energy invested" is controversial. See, for example, the analysis described in https://www.sciencedaily.com/releases/2019/07/190711114846.htm. It is true that biomass is a renewable technology that has a low EROI, but wind and solar have been increasing the EROI as the EROI for fossil fuels decreases. It is no longer clear that fossil fuels have this advantage. Both perspectives should be presented to be accurate.	Noted. The text is based on the messages derived from our synthesis of peer-reviewed literature	Sarah Kurtz	University of California Merced	United States of America
52203	45	47	45	48	EROI is not a cost.	Noted. We do not intend for EROI to be representative of economic costs, rather it is provided as a metric of the overall life-cycle energy requirement for the fuel.	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
55715	45	47	46	6	These sentences include references to energy return on investment (EROI). This metric is interesting and seems like it could provide useful insights for comparing different energy resources. Does the data exist to allow for such a comparison to be included in this chapter?	Noted. While this is an important discussion, we cannot include it because of space constraints.	Government of United States of America	U.S. Department of State	United States of America
1057	46	4			the exploitation , energy-intensive	Rejected. Comment unclear	Alok Dhaundiyal	Szent Istvan University	Hungary
79659	46	8			It is difficult to say that it causes considerable economic impact because these reserves are not and will not be in the economy. This losses have no direct impact in the economy as for instance the crisis of 2008 which withdrawn considerable economic assets.Shall we say " causing considerable potential capital (or revenue) losses" .	Noted. Further discussion provided within the box on stranded assets	Marc Daras	CentraleSupelecAlumni	France
1059	46	9			check the sentence 'resources are'	Accepted.	Alok Dhaundiyal	Szent Istvan University	Hungary
10935	46	9	46	9	delete "resources are" because it is overlapped	Accepted.	Dong-Woon NOH	Korea Energy Economics Institute	Republic of Korea
16359	46	9	46	9	delete "resources are" because it is overlapped	Accepted.	Government of Republic of Korea	Korea Meteorological Administration (KMA)	Republic of Korea
28617	46	9	46	11	Although more recent work has shown that there is enough CCS CO2 storage capacity for much of the fossil reserves to be used, Budiniset al (2017) "Can CCS unlock unburnable carbon", Energy Procedia V114 p7504, Budinis et al (2018) "An assessment of CCS costs, barriers and potential", Energy Strategy Reviews 22 (2018) 61-81, and IEAGHG (2016) "Can CCS unlock unburnable carbon", IEAGHG 2016-05	Taken into account. This has been discussed in section 6.7.4	Tim Dixon	IEAGHG	United Kingdom (of Great Britain and Northern Ireland)
86535	46	9	46	9	"While global fossil energy resources are resources are greater than 500,000 EJ," is 200,000 all fossil resources or just coal? The 500,000 figure is used above to refer to coal alone	Accepted.	raphael Slade	Imperial college	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
79661	46	12			In the same spirit write " to USD 1-5 trillion at present value"	Accepted.	Marc Daras	CentraleSupelecAlumni	France
43577	46	14	46	23	Please add some discussion of the environmental hazards related to the transportation and storage of fossil fuels. There is a wide literature on this, particularly about oil spills from tankers and pipelines.	Noted. While this is an important discussion, we cannot include it because of space constraints.	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy
47047	46	14	46	15	Why aren't the adverse impacts on nearby ecosystems and biodiversity not mentioned in this statement?	Taken into account. Some of such discussion may be found in section 6.7.7.	John Leo Algo	Living Laudato Si' Philippines	Philippines
64285	46	14	46	23	The impact of fugitive methane emissions from oil & gas operations is significant. For instance, a 2020 study shows that satellite measurements of methane emission from a large US oil basin were much higher than government estimates (https://advances.sciencemag.org/content/6/17/eaaz5120). Another article published on ESA webpage indicates that a number of ultra-emitters (large methane emission events) goes unreported but can now be tracked using satellite imagery (https://www.esa.int/Applications/Observing_the_Earth/Copernicus/Sentinel-5P/Mapping_methane_emissions_on_a_global_scale). In March 2021, a study published on the ESA webpage showed that several methane emission events could be detected around pipeline installations in Russia and other countries (https://www.esa.int/Applications/Observing_the_Earth/Copernicus/Sentinel-5P/Monitoring_methane_emissions_from_gas_pipelines).	Noted. While this is an important discussion, we cannot include it because of space constraints.	Christian Lelong	Kayrros	United Kingdom (of Great Britain and Northern Ireland)
15103	46	24	46	29	I'm glad to see that the author mentioned the water demand of unconventional oil and gas resources exploitation. It is suggested to add more discussions on it, air quality and water pollution, such as the following literature: Y. Qin, L. Höglund-Isaksson, E. Byers, K.S. Feng, F. Wagner, W. Peng, and D. L., Mauzerall (2018), Air Quality-Carbon-Water Synergies and Trade-offs in China's Natural Gas Industry. Nature Sustainability 1 (9): 501-508.	Accepted. Reference provided	Guoquan HU	National Climate Center of China Meteorological Adminstration	China
80457	46	25	46	27	Please add values for the water consumption here, for example by changing the sentence "The overall water footprint...fracturing requirements (Scanlon et al. 2017; Kondash et al. 2018)." to "the overall water footprint...fracturing requirements, for example the water use intensity for tight oil is about 1 liter of water for 1 liter of oil extracted. (Scanlon et al. 2017; Kondash et al. 2018)." (The US United States Government Accountability Office puts the estimate even higher "GAO's review of available studies indicated that the expected total water needs for the entire life cycle of oil shale production range from about 1 barrel (or 42 gallons) to 12 barrels of water per barrel of oil produced from in-situ (underground heating) operations, with an average of about 5 barrels, and from about 2 to 4 barrels of water per barrel of oil produced from mining operations with surface heating, with an average of about 3 barrels." See https://www.gao.gov/assets/gao-11-929t.pdf	Noted. While this is an important discussion, we cannot include it because of space constraints.	Moritz Riede	University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
9521	46	30	46	42	There is an extensive literature on how fracking of shale gas is perceived by the public and often objected to. Yet this literature is not mentioned in this text at all. I suggest you include some literature from the US and Europe to address this important gap (e.g. https://doi.org/10.1016/j.enpol.2016.07.032). This is particularly important given that countries like the UK have brought in energy policies to effectively ban shale gas extraction due to social acceptance concerns.	Accepted. Reference provided	Patrick Devine-Wright	University of Exeter	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
27723	46	30	46	30	Delete "Oil and coal consistently rank among the least preferred energy sources in many countries."	Accepted. Text modified	Eleni Kaditi	Organization of the Petroleum Exporting Countries, OPEC	Austria
1061	46	31			relatively low costs	Rejected. Comment unclear	Alok Dhaundiyal	Szent Istvan University	Hungary
69553	46	31	46	32	Why would the IPCC suggest measures to increase the acceptabiity of fossil fuels?	Noted. That is not the intent of this paragraph. Our messages are based on the literature synthesis without any policy preference.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
45915	46	38	46	39	The finding contradicts the statement on page 39 which says that the acceptance of CCS is lower than for renewable energies. How can acceptability of two parts with low acceptability increase when they are combined? Therefore, please explain or delete this sentence.	Noted. Fossil fuels with CCS may have higher acceptability than fossil fuels without CCS in some places.	Government of Germany	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety International Climate Policy	Germany
27725	46	43	46	48	Analysis should refer to inefficient fossil fuel subsidies that encourage wasteful consumption.	Taken into account. Fossil fuel subsidies have been discussed in Box 6.3 separately.	Eleni Kaditi	Organization of the Petroleum Exporting Countries, OPEC	Austria
43751	46	43			Please be more precise: what do these estimates depend on? How do they compare to renewable subsidies? How have they developed over time? Inefficiencies resulting from fossil fuel subsidies have been assessed and should be featured more clearly (e.g. as in SR1.5).	Taken into account. Fossil fuel subsidies have been discussed in Box 6.3 separately.	Government of Jamaica	Meteorological Service Division	Jamaica
48739	46	43	46	43	Suggest to change “Fossil fuel subsidies have been valued of the order of USD 0.5-5 trillion annually by various estimates” to “Fossil fuel subsidies have been valued of the order of USD 0.5-5 trillion annually by various estimates and methodologies”. Reason: strong disputes exist in definition and methodologies of fossil fuel subsidies globally (as suggested in page 22 Box 6.3 of this chapter). To make the expression more objective, suggest to mention the differences in methodologies here.	Taken into account. Fossil fuel subsidies have been discussed in Box 6.3 separately.	Qi An	Energy Research Institute, National Development and Reform Commission of China	China
80459	46	44	46	46	There is a more up-to-date reference for this: IRENA’s 2020 report on “Energy Subsidies: Evolution in the Global Energy Transformation to 2050” https://www.irena.org/publications/2020/Apr/Energy-Subsidies-2020. It estimates the direct subsidies for fossil fuels USD 3.1 trillion, confirming the range provided with more up-to-date data.	Taken into account. Fossil fuel subsidies have been discussed in Box 6.3 separately.	Moritz Riede	University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
69555	46	45	46	45	I guess what is meant is that fossil fuel subsidies have a tendancy to introduce economic efficiency, but the sentence currently reads as if the estimates of subsidies were introducing economic efficiency.	Taken into account. Fossil fuel subsidies have been discussed in Box 6.3 separately.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
43881	47	1	47	1	This comment may also afect other energy resources. It would be better if a resource map of areas with geothermal energy potentials would be included in Section 6.4.2.8. These locations may include those areas along the Pacific Ring of Fire and those areas with acquifers.	Rejected.word allocation restrcit adding a map	Vince Davidson Pacañot	University of the Philippines Diliman	Philippines

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
69557	47	1			The section on geothermal should start by distinguishing the potential for low or very low temperature heat aka very low energy geothermal, and that for high temperature heat and power (itself divided by convective hydrothermal resources, and hot dry rock resources). Low temperature heat resource can be accessed with a variety of technologies to deliver low temperature heat to building and some agriculture and industrial activities, including through tthe use of geothermal heat pumps to lift up the temperature level.	Rejected. Space limit. We have however provided breakdown for electricity general and thermal end uses	Cédric PHILIBERT	Institut Français des Relations Internationales	France
85345	47	1	48	19	the section on geo thermal would do well to look in detail at New Zealands	Accepted depending on space limit. A limited number of countries have a long history in geothermal and, a least, in one country geothermal accounts for 20% of electricity generation (https://nzgeothermal.org.nz/geothermal-energy/electricity-generation/)	Linda Hancock	Deakin University	Australia
17373	47	2	47	2	give a number of currently generated energy from geothermal (TWh-electric and TWh-heat)	Accepted depending on space limit.	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
80461	47	2	47	3	Please add the values for the current generation of geothermal resources. It is not mentioned in this section, but would improve it.	Accepted	Moritz Riede	University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
79663	47	4			add after electricity "depending of the temperature of the source" since high to moderate temperature is needed for producing electricity with a turbine.	Accepted. Comment will be added	Marc Daras	CentraleSupelecAlumni	France
4115	47	9	47	10	"There is an enormous potential for direct geothermal heat ..." To be comparable with the subsequent text, the potential, as well as the actual supply, may well be stated in comparison to the current global energy consumption.	Accepted, space allocation permitteed	Tatsuki Ueda	National Agriculture and Food Research Organization	Japan
43579	47	9	47	13	Acquifers matter both for eating and cooling. It is the differential w.r.t surface indoor temparatures that can be exploited to attain heating/ccoling needs	Accepted. There is an enormous potential from aquifers for heating and cooling, yet	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy
60167	47	11	47	13	It should be mentioned that CH4/CO2 emissions can be coupled with geothermal energy production	Rejected.Compared with fossil fuels, emissions are relatively low.	Government of Hungary	Ministry of Innovation and Technology - Climate Policy Department	Hungary
84333	47	11	47	13	Please add a map to fix the potentials.	Rejected.Space allocation	Vincent MAZAURIC	Schneider Electric	France
64137	47	15	47	16	2010' in title of Figure 6.16 is strange. It may be deleted or be modified to 2010-2018	Accepted- will be amended 2010-2020	Ghulam Rasul Athar	Pakistan Atomic Energy Commission	Pakistan
45495	47	16	47	16	2010 should be: 2010 - 2018	Accepted-same as above	Kornelis Blok	Delft University of Technology	Netherlands
5357	47	22	47	27	I recommend you mention also power plants dedicated to heating, either indusrial or domestic.	Rejected.Heatng already dealt with. Lines 5 to 10.	Michel SIMON	Retraité/ Pdt d'association	France
1063	47	23	24		remove semi colon use ','	Accepted for the second semi colon	Alok Dhaundiyal	Szent Istvan University	Hungary

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
74869	47	25	47	28	Geothermal plants, used to meet baseload demand due to low costs that are flash steam plants are inflexible. This contributes to the rising challenge of venting steam from geothermal fields and wastign resources. It is recommended that the binary cycle technology be adopted	Rejected. Space limit to dscuss baseload issue	Government of Kenya	Kenya Meteorological Service	Kenya
1065	47	27	28		check the sentences	Accepted. Sentence shortened	Alok Dhaundiyal	Szent Istvan University	Hungary
27727	47		47		Figure 6.16 to have the title corrected and refer to the period 2010-2018.	Accepted.	Eleni Kaditi	Organization of the Petroleum Exporting Countries, OPEC	Austria
14815	48	3	48	6	While e.g. geothermal heat pumps are technically mature, it may be worth mentioning that successful large-scale deployment of shallow geothermal energy in particular will depend not only on site-specific economic performance, but also on the development of suitable governance frameworks; several policy and management challenges are already starting to emerge in the context of urban areas with denser use of the technology, despite a fairly early stage of adoption overall relative to the technology's potential - e.g. improved planning approaches are increasingly called for to manage thermal interferences between borehole or groundwater heat pump systems, competition with other subsurface uses, and long-term uncertainties more broadly. See e.g. Garcia-Gil et al., 2020, https://doi.org/10.1016/j.enpol.2020.111283 ; Bloemendal et al., 2018, https://doi.org/10.1016/j.apenergy.2018.02.068	Accepted. Ref and comment will be taken into consideration	Marc Jaxa-Rozen	University of Geneva	France
28945	48	3	48	3	Please add: ...in the demonstration stage (IRENA 2018), or shallow-geothermal energy, which uses the upper few meters below the ground and represent a promising supply source for building heating and cooling demands (Refer to: Narsilo, Aye 2018: Shallow Geothermal Energy: An Emerging Technology)	Accepted. Will be added	Fabian Heymann	INESC TEC	Switzerland
4113	48	5	48	6	Fig. 6.16 seems to show a historical trend of cost and other factors concerning geothermal energy, while the corresponding text discusses about diversity as to sites. Please be more consistent, or better to remove the figure if it is not meaningly discussed in test.	Rejected. No need to comment the figure. It is sufficiently explicit.	Tatsuki Ueda	National Agriculture and Food Research Organization	Japan
55717	48	5	48	6	Recommend inserting a sentence stating: "Geothermal non-electric sector technologies' limited adoption is a consequence of a lack of public awareness and a lack of policy innovation and application, as well as innovation in business and financing models that can help amortize the high capex of these systems for the consumer." Adoption of solar PV has realized great success through these innovations and the same is needed for geothermal.	Rejected. No sufficient confidence and references to add this statemet	Government of United States of America	U.S. Department of State	United States of America
17909	48	7	48	9	GHG emissions from geothermal should be added here. E.g. ESMAP Tech Report 009/16	Rejected. The purpose of this sentence is to address environmental issues apart from GHG emissions. Furthermore, compared with fossil fuels geothermal GHG emissions are not particularly high.	Robert Brecha	Climate Analytics	Germany
19187	48	7	48	9	statement 'geothermal has several adverse environmental impacts' has to be back with clear data, otherwise the statement is very broadly worded. The section on geothermal doesn't mention potential for hot water from geothermal which can be extracted at temperatures below 150C - a very important potential particularly in developing countries, see: https://climatechangeconnection.org/solutions/alternative-heat-energy/geothermal/	Partially accepted. Potential for hot water will be added	Andrei Belyi	University of Eastern Finland	Finland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
20997	48	7	48	7	About "[...] air pollution", we suggest to add a citation	Accepted. Ref will be added	Government of France	Ministère de la Transition écologique et solidaire	France
43581	48	7	48	9	I think here you need to distinguish between large scale, high temperature geothermal power generation plants and low scale, low temperature geothermal use for heating and cooling. The latter is much less problematic for the environment.	Accepted. Related to above.	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy
43883	48	7	48	9	Although the assesment is high confidence, I would recommend to substantiate this statement with studies detailing the adverse effects of geothermal energy production. One study that I am familiar with is that of Pratiwi and Juerges (2020) [19], which details the impacts of other renewable energy resources through literature reviews. Most common impact of renewable energy production, such as geothermal energy, include habitat destruction both for aquatic (freshwater) and forest species.	Accepted	Vince Davidson Pacañot	University of the Philippines Diliman	Philippines
45917	48	7	48	19	Please rewrite these paragraphs. A more differentiated view regarding environmental risks of geothermal energy should be applied. The effects differ widely over the specific geothermal technologies mentioned and none of the effects occur on a regular basis or could not be abated! References: Lohse, C., 2018, Environmental impact by hydrogeothermal energy generation in low-enthalpy regions, Renewable Energy 128 (2018), pp. 509-519. http://dx.doi.org/10.1016/j.renene.2017.06.030 Ragnarsson et al (45 authors), 2020, Report on environmental concerns – Overall state of the art on deep geothermal environmental data, GEOENVI report D.2.1, November 2020, https://www.geoenvi.eu/ Shallow Geothermal Systems, 2016, German Geological Societey, https://onlinelibrary.wiley.com/doi/book/10.1002/9783433606674 Vienken et al, 2019, Monitoring the impact of intensive shallow geothermal energy use on groundwater temperatures in a residential neighbourhood, Geotherm Energy 7,8 (2019). https://doi.org/10.1186/s40517-019-0123-x Pratiwi, A.S., Trutnevyte, E., 2020, Review of Life Cycle Assessments of Geothermal Heating Systems, In: Proceedings World Geothermal Congress 2020. 2020. http://archive-ouverte.unige.ch/unige:132023	Accepted. This will be reformualated	Government of Germany	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety International Climate Policy	Germany
55719	48	7	48	9	What are examples of the adverse environmental impacts suggested in this sentence?	Rejected. Examples are given. However sentence will be reformulated	Government of United States of America	U.S. Department of State	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
55721	48	7	48	9	Recommend replacing with the following statement: "With the implementation of modern technologies, geothermal presents minimal adverse environmental impacts." As currently written this statement is misleading. The impacts referred to here are legacy of a time when resource development and management technologies were crude. They generally don't occur for modern geothermal developments. For example, discharge of Wairakei (NZ) geothermal fluids to the Waikato river, and all the environmental impacts associated with that (including subsidence) would now be fully mitigated by modern geothermal development practices that employ injection to maintain reservoir pressures and ensure resource sustainability. Furthermore, while it is true that flash plants do emit some GHGs, they do so on a far lower lifecycle CO2eq/MWh basis than virtually any other technology apart from hydropower and nuclear. As geothermal energy recovery technologies improve, increasing amounts of binary generation technologies are now being utilized instead of flash steam power plants. This will result in 100% injection and essentially zero GHG emissions.	Accepted. Comment will be taken into consideration	Government of United States of America	U.S. Department of State	United States of America
63169	48	7	48	9	These negative impacts pertain to geothermal plants, but not to geothermal heat pumps, which can provide heating and cooling for buildings.	Accepted. Paragraph will be reformulated	Jennifer Sklarew	George Mason University	United States of America
55723	48	8	48	8	Remove the word "catastrophic" as it is misleading given modern technologies and safety protocols. For example, seismic events vary in severity. All geothermal developments generate some microseismicity -- as do other energy generation resources -- but the "micro" part is the key. When properly managed and when the appropriate protocols are implemented, this is not an issue for geothermal.	Accepted. Catastrophic will be removed	Government of United States of America	U.S. Department of State	United States of America
9523	48	10	48	19	There is no mention in the section on Marine Energy on the topics of public perceptions and community acceptance, yet studies have been conducted on both tidal and wave energy projects that have shown some of the reasons why people and stakeholders might support or object to the different technology types in different ways (e.g. https://doi.org/10.1016/j.jenvp.2011.07.001; http://dx.doi.org/10.1016/j.ijome.2016.01.007; doi:10.1016/j.enpol.2009.07.057).	Not related to geothermal but marine energy	Patrick Devine-Wright	University of Exeter	United Kingdom (of Great Britain and Northern Ireland)
14813	48	10	48	13	See also the studies of energy technology preferences in Volken et al. (2018) and Dubois et al. (2019), which assessed changes in preferences after providing workshop participants with informational materials. While the initial perception of deep geothermal energy was relatively positive and similar to other renewable technologies, this perception was highly sensitive to engagement with information materials, and the short-term change in preferences was significantly negative in both studies. Overall, this supports the point that public opinion of deep geothermal energy remains largely unformed, and will likely evolve as more knowledge emerges about the technology. http://dx.doi.org/10.1021/acs.est.8b01265 ; https://doi.org/10.3390/en12224231	Accepted. Ref and comment will be taken into consideration	Marc Jaxa-Rozen	University of Geneva	France
63175	48	13			Waste-to-energy plants that do not have sufficient filters can emit toxins, and ash produced from these facilities also contains toxins. Deployment of waste-to-energy requires regulatory controls on emissions, technological solutions to address toxins, and justice considerations regarding siting. Public perceptions of these environmental concerns have challenged siting in some locations in the United States.	rejected. This is not about waste to energy	Jennifer Sklarew	George Mason University	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
1067	48	14			instalment	Accepted. Other word will be suggested	Alok Dhaundiyal	Szent Istvan University	Hungary
55725	48	16	48	16	Suggest revising statement to say: "As with almost all electricity generation projects, noise and impacts to the landscape have been reasons for protests against specific geothermal projects." These have been reasons to protest virtually every single power development project -- regardless of power generation technology. Regarding the concerns over "smell", citing this is unnecessary. Typically this relates to the "rotten egg" smell of H2S gas. This is almost always a natural feature of the site -- owing to the natural occurrence of the geothermal resource in that location. That smell would be present with or without the geothermal development.	Accepted. Comment will be taken into consideration	Government of United States of America	U.S. Department of State	United States of America
18235	48	20	48	37	(Section 6.4.2.9) This section would perhaps benefit from a brief discussion of the potential ecosystem and biodiversity impacts and trade-offs associated with marine energy technologies. There are also no references to levels of confidence / agreement in this section.	Rejected due to lack of available space in the section.	Government of United Kingdom (of Great Britain and Northern Ireland)	Department for Business, Energy & Industrial Strategy	United Kingdom (of Great Britain and Northern Ireland)
20999	48	20	48	20	The figures given for the technical potential are sometimes unclear. Is it about the ressources only or does it take into account exclusion area where it is impossible to put offshore renewable energies at sea due to curent activities (such as marine traffic, fishing, military activities, etc) and protected areas ?	Taken into account. The resources cited in the text are purely from the geophysical perspective. An explanation is given	Government of France	Ministère de la Transition écologique et solidaire	France
21001	48	20	48	20	The growth of marine renewable energies will result in the increasing use of sea space and potential for conflict with existing marine uses, both of which can be addressed, in part, through implementation of Marine Spatial Planning. Marine Spatial Planning and Marine Renewable Energy Anne Marie O'Hagan, Dorian M. Overhus and Mikaela C. Freeman https://doi.org/10.2172/1633204	Taken into account. A short sentence has been added.	Government of France	Ministère de la Transition écologique et solidaire	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
21003	48	20	48	20	This part is pretty weak and could be way more interesting. It does not pay tribute to a sector with such potential for present and future energy needs. Here some examples are given, some data is shown, but the overall message can be enhanced. What is more, talking about offshore wind power is important. Even if not directly linked with marine dynamics, it is integrated within it and has some serious implications for the Marine Energy mix. (IEA (2019). Offshore wind outlook 2019. Available at: https://www.iea.org/reports/offshore-wind-outlook-2019) Furthermore, a part about marine energy threats and concerns could be of great interest. (Goffetti Giulia, Montini Massimiliano, Volpe Francesca, Gigliotti Massimo, Pulselli Federico M., Sannino Gianmaria, Marchettini Nadia. (2018). Disaggregating the SWOT Analysis of Marine Renewable Energies. Frontiers in Energy Research. Volume 6 Page 138. DOI=10.3389/fenrg.2018.00138) (PMI Industries (2016). Challenges in the Installation and Repair of Marine Energy Devices. Available at: https://pmiind.com/marine-energy-devices-challanges/) (PMI Industries (2017). Five Complications for Tidal and Waves Energy Devices. Available at: https://pmiind.com/5-complications-tidal-wave-energy-devices/) Common environmental concerns associated with marine energy developments include: • the risk of marine mammals and fish being struck by tidal turbine blades (Schoeman, R., Patterson-Abrolat, C., & Plön, S. (2020). A Global Review of Vessel Collisions With Marine Animals. Frontiers in Marine Science.) • the effects of EMF and underwater noise emitted from operating marine energy devices (Thomsen, Frank & Gill, A. B. & Kosecka, Monika & Andersson, Mathias & André, Michel & Degraer, Steven & Folegot, Thomas & Gabriel, Joachim & Judd, Adrian & Neumann, Thomas & Norro, Alain & Risch, Denise & Sigray, Peter & Wood, Daniel & Wilson, Ben. (2016). MaRVEN – Environmental Impacts of Noise, Vibrations and Electromagnetic Emissions from Marine Renewable Energy. 10.2777/272281.)	Rejected due to lack of available space in the section.	Government of France	Ministère de la Transition écologique et solidaire	France
43885	48	20	48	37	To support the fact that technological barriers hinder the development of marine or ocean energy, you can use the image provided in the August 2014 Ocean Energy report by the International Renewable Energy Agency [20]. The figure, which shows the technological readiness of different ocean energy technologies, is located on page "xi" or page 13/76 of the PDF document.	Accepted. A final sentence on the maturity and perfomance of the ocean technologies has been added.	Vince Davidson Pacañot	University of the Philippines Diliman	Philippines
45497	48	20	48	37	Ocean thermal energy conversion (OTEC) is missing. There are some interesting papers by one of my PhD students: Langer, J., Quist, J., & Blok, K. (2020). Recent progress in the economics of ocean thermal energy conversion: Critical review and research agenda. Renewable and Sustainable Energy Reviews, 130, [109960]. https://doi.org/10.1016/j.rser.2020.109960, and: Langer et al.: Plant siting and economic potential of ocean thermal energy conversion in Indonesia A novel GIS-based methodology, Energy https://doi.org/10.1016/j.energy.2021.120121	Taken partly into account. The OTEC name is not used, but the technology and potential is described. A clarification has beeen added.	Kornelis Blok	Delft University of Technology	Netherlands
47049	48	20	48	37	It might be better to include in this section a few examples of tidal energy, however briefly.	Rejected due to lack of available space in the section.	John Leo Algo	Living Laudato Si' Philippines	Philippines
55727	48	20	48	37	Section could mimic others to include synthesis of environmental and social considerations.	Rejected due to lack of available space in the section.	Government of United States of America	U.S. Department of State	United States of America
2661	48	21	48	37	Please use consistent units in this paragraph. Using both TW and Twh makes it unneccesarily difficult to compare numbers	Taken into account. The text has been revised and the same units are used.	Jan Wohland	ETH Zurich	Switzerland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
2663	48	21	48	37	This paragraph fails to address the immaturity of some of the mentioned technologies. Quoting from Kempener and Neumann (2014d): "There are two technologies for which demonstration projects are running and both use membranes." "The relatively small experience base with salinity gradient technology also has consequences for policy makers, as technology developers look for support and stability to continue to demonstrate this technology. Unfortunately, due to the lack of reliable financial support mechanisms, the company Statkraft, which is one of Europe's largest generators of renewable energy and a the leading power company in Norway, is going to discontinue its osmotic power efforts this year (2014) and is looking for investors to continue with the research and results attained over the 2006-2014 period."	Accepted. A final sentence on the maturity and perfomance of the ocean technologies has been added.	Jan Wohland	ETH Zurich	Switzerland
71595	48	21	48	21	The ocean - singular form is better suited.	Accepted	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
45521	48	22	48	22	It would be accurate to rename 'ocean thermal gradient' to 'ocean thermal energy conversion' (OTEC). In the field, OTEC is the common term for the technology.	Accepted	Kornelis Blok	Delft University of Technology	Netherlands
69559	48	23	48	27	The capacity factor of tidal plants being about 25% or 2200 full load hour equivalent at best, so that 1 TW converts in about 2200 TWh of electricity. This information might of interest to the reader.	Rejected due to lack of available space in the section.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
69561	48	23	48	27	f; Lemperiere has proposed the concept of tidal basins to take advantage of lower tide ranges and in-stream turbines, and assessed its world potential at ~20 000 TWh. Tidal basins could be assuming some additional storage functions and coupled with pumpage. The Tidal lagoon proposed on the Severn river in the UK would be an close illustration of the concept. Furthermore, tidal basins could also protect coastal cities from sea level rise. Lempérière F., 2014, New solution could double world tidal energy potential at half the cost, Hydropower & Dams, issue One.	Rejected due to lack of available space in the section.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
80463	48	23	48	24	maybe add that tidal energy is caused by the moon	Noted.	Moritz Riede	University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
80465	48	27	48	29	maybe add that wave energy is caused by winds	Noted.	Moritz Riede	University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
1069	48	28			remove 'from' pressure..	Accepted	Alok Dhaundiyal	Szent Istvan University	Hungary

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
69563	48	30	48	37	Tidal energy should be distinguished from others here, as it is much more realistic. Thermal ocean energy is unlikely to ever deliver power cost-effectively on the basis of a small temperature difference of about 20°C, which implies a Carnot efficiency of heat to power of less than 7% in ideal condition, still much less in practice. By comparison, non-concentrating solar thermal power, with cheap storage of hot water to run baseload or in a controlable mode, could exploit a temperature difference of 60 to 80°C, offering a theoretical Carnot efficiency of 21% - but it is not deployed due to costs and competition with PV and CSP.	Accepted. A final sentence on the maturity and perfomance of the ocean technologies has been added.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
69565	48	30	48	37	This paragraph misses the real potential of ocean thermal energy, which is to offer both free cooling and free heat (via heat pumps) to coastal cities, buildings and activities (e.g. data centers). Microsoft has alreated tested the installation of a datacentre under sea water. A 180 MW heat pump delivers heat from the Baltic sea to the district heating grid of Stockholm. This potential is likely quite important.	Accepted. An additional sentence has been added.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
45523	48	31	48	31	Kempener and Neumann (IRENA) only reviewed the potentials, but the 30 TW stem from Rajagopalan & Nihous (2013) and I think it is fair to place the primary source here.	Accepted. The text has been revised.	Kornelis Blok	Delft University of Technology	Netherlands
21005	48	34	48	34	About "[...] highly regular": Interannual variations of wind and wave energy is not negligible. https://hal.archives-ouvertes.fr/hal-01865260 Nicolas Guillou, Georges Chapalain. Wave Energy Potential in the Sea of Iroise. 11th European Wave and Tidal Energy Conference Series, Sep 2015, Nantes, France. ffhal-01865260f	Accepted. The text has been revised.	Government of France	Ministère de la Transition écologique et solidaire	France
5359	48	35	48	37	In addition, it is doubtgul that these marine energies bay be become economically viable.	Accepted. A final sentence on the maturity and perfomance of the ocean technologies has been added.	Michel SIMON	Retraité/ Pdt d'association	France
84335	48	35	48	37	Maintenance costs could be also important (e.g.: tidal current power, pelamis...) regarding the diluted generation.	Rejected due to lack of available space in the section.	Vincent MAZAURIC	Schneider Electric	France
4179	48	37	48		Some examples of environmental imapcts would be helpful to include, such as: migrating pacific salmon and breeding arctic whales. It should also be mentioned that the unpredictabilty of ocean currents (thermocline and halocline changes) influenced by melting sea ice and expanding warm ocean waters introduces difficult parameters to include when discussing the feasibility of marine energy generation.	Rejected due to lack of available space in the section.	Neil M. Mulchan	Adventure Physics, LLC	United States of America
361	48	38	49	13	It should be mentioned here that waste-to-energy can be combined with CCS resulting in negative emissions. In Norway such plants are evaluated, see here for scitiefic publication with cost estimates: https://www.frontiersin.org/articles/10.3389/fenrg.2020.00017/full and there are already globally for plants with carbon capture installed: https://www.sciencedirect.com/science/article/pii/S036054422030459X See also these feasibility studies by ETH Zurich lab: https://www.suslab.ch/special-ccs .	Thank you. We have incorperated the impact of integration of CCS and WTE in the revised draft	Bastien Girod	ETH Zurich	Switzerland
18237	48	38	49	13	(Section 6.4.2.10) This section would benefit from a more detailed discussion of the trade-offs. For example, the need to focus first on reuse and recycling waste, before converting residual waste to energy, and the risk of trade-offs such as waste-to-energy lowering incentives to reduce waste and therefore negatively impacting efficiencies in the economy (i.e., reducing the chances of achieving circular economies).	Thank you. However, due to the expected limited length of the section, such detail analysis could not be done	Government of United Kingdom (of Great Britain and Northern Ireland)	Department for Business, Energy & Industrial Strategy	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
18239	48	38	49	13	(Section 6.4.2.10) This section should discuss the impacts and importance of regulation of the waste to energy sector. E.g., fertilisers generated from waste to energy technologies can be highly polluting if not properly regulated.	We have elaborated more on the importance of proper regulation of the WTE sector and the negative impacts of improper regulation	Government of United Kingdom (of Great Britain and Northern Ireland)	Department for Business, Energy & Industrial Strategy	United Kingdom (of Great Britain and Northern Ireland)
18241	48	38	49	13	(Section 6.4.2.10) this section would benefit from more assessments of the confidence and agreement of the evidence presented.	We have made more assessment of the evidence provided to boost confidence	Government of United Kingdom (of Great Britain and Northern Ireland)	Department for Business, Energy & Industrial Strategy	United Kingdom (of Great Britain and Northern Ireland)
79781	48	38	49	13	The SECTION 6.4.2.10 Waste to energy is rather poor and do not present the potential contribution of the sector. Economically speaking, a report provides significant potential for development (see Grand View Research, Waste To Energy Market Size, Share & Trends Analysis Report By Technology (Thermal (Incineration, Gasification, Pyrolysis), Biological), By Region (North America, Europe, APAC, Central & South America, MEA), And Segment Forecasts, 2020 - 2027). The issues related to increased recycling potential that the implementation is given is not presented (see e.g https://doi.org/10.1016/j.wasman.2008.11.020, where the additional benefits on recycling, land conservation and CO2 emissions reduction is clearly presented). Furthermore, it is of paramount importance to present the fact that the greener cities of the world wave included in their approach for sustainable development Waste-to-Energy technologies (https://doi.org/10.1108/MEQ-01-2015-0018). Also, the substitution of coal on existing power plants from waste-derived fuels as an viable and already applied approach in Waste-to-Energy can support further the decarbonization of Power Sector and reduce the investment costs in new infrastructures. Psomopoulos, Kakaras and many others have already demonstrated this through their publications e.g. https://doi.org/10.1080/15567036.2011.639845, https://doi.org/10.1080/10473289.2003.10466304,	The section has been revised. But due to the limited length for this section, we are more focused on the waste to energy technology advantages and disadvantages.	Constantinos Psomopoulos	University of West Attica, Department of Electrical and Electronics Engineering	Greece
17835	48	39	49	13	This Waste-to-Energy section needs to mention both the emissions reduction and negative net emissions potential when paired with CCS. There are examples of projects of Wte with CCS (e.g. Twence in the Netherlands, Klemutsrud in Norway). As some fuel in WtE plants is biomass, negative emissions is possible so long as sufficient CCS is undertaken to capture more than the non-biogenic fraction of the CO2 produced. WtE also does not have the upstream emissions challenges of fertiliser N2O emissions or LULUCF. References: 1) Paulina Wienchol, Andrzej Szlęk, Mario Ditaranto, Waste-to-energy technology integrated with carbon capture – Challenges and opportunities, Energy, Volume 198, 2020, 117352, ISSN 0360-5442, https://doi.org/10.1016/j.energy.2020.117352. 2) https://www.globalccsinstitute.com/wp-content/uploads/2019/10/Waste-to-energy-with-CCS_A-pathway-to-carbon-negative-power-generation_Oct2019-4.pdf 3) ICEF 2020 Roadmap: Biomass Carbon Removal and Storage (BiCRS) https://www.icef-forum.org/roadmap/	We have included the emission reduction and negative emission potential of integrating CCS and WTE	Eve Tamme	Global CCS Institute	Belgium

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85977	48	39	48	40	Suggest clarification: 'Waste-to-energy describes technologies that convert waste (organic and inorganic fraction) into energy such as heat, fuel, and electricity.' Can the authors please check the accuracy of this sentence, waste-to-energy plants only convert the organic fraction of wastes to energy. The inorganic fraction is not converted to energy.	Accept	Government of Australia	Department of Industry, Science, Energy and Resources	Australia
1071	48	42			write it properly 'mitigatHion'	Accept	Alok Dhaundiyal	Szent Istvan University	Hungary
10937	48	42	48	42	change "mitigatHion" to "mitigation"	Accept	Dong-Woon NOH	Korea Energy Economics Institute	Republic of Korea
16361	48	42	48	42	change "mitigatHion" to "mitigation"	Accept	Government of Republic of Korea	Korea Meteorological Administration (KMA)	Republic of Korea
17513	48	42	48	42	Typo: mitigatHion	Accept	Alaa Al Khourdajie	IPCC	United Kingdom (of Great Britain and Northern Ireland)
28377	48	42	48	42	Mitigation is mispelt	Accept	Sanjay Kuttan	Singapore Maritime Institute	Singapore
43185	48	42	48	43	This sentence does not have a quote and should be edited to clarify what WTE technologies it refers to. WTE includes waste incineration, which is not considered a low carbon technology but a net contributor to climate change. Incinerating municipal solid waste directly releases between 0.7 and 1.7 tonne of CO2 per tonne of waste, depending on waste composition. This includes emissions of both fossil CO2 (e.g. from burning plastics) and biogenic CO2 (e.g. from burning wood, paper and food). Although biogenic CO2 directly released into the atmosphere makes a significant contribution to climate change, biogenic CO2 is often excluded from global emissions analysis and is an important loophole in GHG emissions accountability (Searchinger, 2009). Searingcher, T. et al. (2009). Fixing a Critical Climate Accounting Error, Science (326:5952) Even if we focus only on emissions due to fossil-based wastes (including most plastics), CO2 emissions from waste incineration are considerable. Incinerating plastic waste is particularly carbon intensive, with the release of around 2 tonnes of fossil CO2 per tonne of dense plastic. Energy produced from incineration with energy recovery is also very carbon intensive. It performs best in a minority of cities where all the waste heat is used directly in a district heating network, with an estimated carbon intensity of 368g CO2eq/kWh in EU incinerators, more than GHGs emitted when burning gas (340g CO2eq/kWh), and 24% more than the average carbon intensity of the EU energy grid in 2018 (296g CO2eq/kWh). Moreover, energy from WTE incineration is heavily polluting. The text should include a reference to the air pollution related to waste incineration. In the first place, waste incineration is known to produce toxic air pollution (fly ash) and toxic ashes (bottom ashes) - 1 ton of MSW produces approximately 0.3 ton of incinerator bottom ash (IBA). Qiao, X. C., et al. "Production of lightweight concrete using incinerator bottom ash." Construction and Building Materials 22.4 (2008): 473-480. These are inevitable byproducts of the waste-to-energy incineration process which should be recognised and included in the text. In the second place, despite regulations and monitoring (which vary in different regions	Thank you very much.According to the comments, I have specifiy the type of WTE technologies with the associated citations and references. Also, a reference in relation to the air pollution from incineration has been provided.	Mariel Vilella	Zero Waste Europe/University of Manchester	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
43583	48	42	48	42	Replace "mitigHation" with "mitigation"	mitigatHion' has been corrected to 'mitigation'	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy
52205	48	42	48	42	"H" is capitalized in the middle of mitigation.	Accept	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
55729	48	42	48	43	Important to caveat here that WTE, when applied with proper air pollution reduction technologies, can provide clean energy and GHG reductions. If not applied properly, it can exacerbate air quality issues.	Thank you very much. The suggested sentences have been incorperated in the revised drafy	Government of United States of America	U.S. Department of State	United States of America
61985	48	42	48	42	Typo: change "contribute to climate mitigatHion via clean" to "contribute to climate mitigation via clean"	Accepted	Esa Vakkilainen	LUT University, Lappeenranta	Finland
63171	48	42			"mitigatHion" needs to be corrected to "mitigation"	Accept	Jennifer Sklarew	George Mason University	United States of America
71597	48	42	48	42	Please change "MitigatHion" to mitigation	Accept	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
71599	48	42	48	42	Text referrs to "electricity production", but nothing said about thermal energy production, so please consider including "thermal energy".	Revised	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
10939	48	44	48	44	change "whiles" to "while"?	Accept	Dong-Woon NOH	Korea Energy Economics Institute	Republic of Korea
16363	48	44	48	44	change "whiles" to "while"?	Accept	Government of Republic of Korea	Korea Meteorological Administration (KMA)	Republic of Korea
28379	48	44	48	44	whiles should be whilst	This has been deleted from the draft	Sanjay Kuttan	Singapore Maritime Institute	Singapore

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
43187	48	44	48	45	Waste-to-energy technologies can reduce the volume of waste whiles producing sustainable energy to 45 meet the current demand. This statement and assessment of energy from WTE as 'sustainable' does not provide a quote. In fact, thermal WTE technologies including incineration, gasification and pirolysis create waste management systems locked into providing large amounts of waste as feedstock to incinerators that prevent dveelopment of sustainable policies. In particular, waste to energy incineration causes a lock in effect at economical, institutional, technological and cultural level which needs to be included in this section. A study of waste incineration in the Göteborg Metropolitan Area, Sweden, serves as an illustrative case. Taking leads from Unruh (2000, 2002), four rationales of lock-in are identified in the case: institutional, technical, cultural, and material. The article describes how these rationales, one by one and in collaboration, lock-in waste handling in the Göteborg Metropolitan Area to incineration. Corvellec, Hervé, María José Zapata Campos, and Patrik Zapata. "Infrastructures, lock-in, and sustainable urban development: the case of waste incineration in the Göteborg Metropolitan Area." Journal of cleaner production 50 (2013): 32-39. https://www.sciencedirect.com/science/article/pii/S0959652612006531	Thank you. Based on the comments the whole sentence has been removed from the draft and other better deescription of incineration taking into consideration it's environmental concequences have been provided	Mariel Vilella	Zero Waste Europe/University of Manchester	United Kingdom (of Great Britain and Northern Ireland)
43193	48	44	49	6	This section makes assessments to different technologies putting them all under the umbrella of waste to energy, which is inaccurate given they are very different technologies. The term waste to energy is in fact a language that originates in the incineration industry in order to emphasise the energy output from incineration. Therefore, it is not appropiatte and if used, it should be clearly defined which WTE technology is being referred to.	The revised section has now clarified the type of WTE technology that is being analyzed	Mariel Vilella	Zero Waste Europe/University of Manchester	United Kingdom (of Great Britain and Northern Ireland)
43585	48	44	48	44	Replace "whiles" with "while"	This has been deleted from the draft	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy
63173	48	44			"whiles" should be corrected to "while"	This has been deleted from the draft	Jennifer Sklarew	George Mason University	United States of America
7865	48	45	48	45	Waste-to-energy sector could potentially provide about 13 GW of electricity -- this value seemed to be pretty low as an overall global resource, so I checked the reference to see if the value was correct. I may have missed it - but there does not seem to be a total global value in the reference.	This has been revised	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
17375	48	45	48	45	13 GW is surprisingly low number	This has been revised	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
71601	48	45	48	45	All focus only on electricity. The number 13 GW is for electricity, but waste to energy also produce thermal energy which makes big share, so please consider to provide numbers on thermal energy.	Figure for both thermal and electricity has been provided. Besides, the 13 GW has been revised	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
47051	48	46	49	1	For consistency's sake, public perception on WTE must also be shown here, as it has been on other energy resources in previous pages. Furthermore, the implications on burning recyclable materials such as plastics on promoting a circular economy should also be included here.	The public perception on WTE has been incorperated in the revised version. Besides, the impact of incinerating recyclable waste has been inserted in the revised draft	John Leo Algo	Living Laudato Si' Philippines	Philippines

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
1073	48	47			article is required	This has been revised	Alok Dhaundiyal	Szent Istvan University	Hungary
43189	48	47	49	2	The source quoted backing up this sentence is not a peeer-reviewed paper but rather the opinion of a consultancy agency based in the US (see https://www.cleanearthinc.com/about-us). In this sense, their opinion is not validated by a peer-reviwed process and should be contrasted with other sources. The text should reflect on the contribution of WTE incineration to climate change mitigation, which is a very controversial matter. Reports show that WTE incineration is in fact a net contributor to climate change Incinerating municipal solid waste directly releases between 0.7 and 1.7 tonne of CO2 per tonne of waste, depending on waste composition. This includes emissions of both fossil CO2 (e.g. from burning plastics) and biogenic CO2 (e.g. from burning wood, paper and food). Although biogenic CO2 directly released into the atmosphere makes a significant contribution to climate change, biogenic CO2 is often excluded from global emissions analysis and is an important loophole in GHG emissions accountability (Searchinger, 2009). Even if we focus only on emissions due to fossil-based wastes (including most plastics), CO2 emissions from waste incineration are considerable. Incinerating plastic waste is particularly carbon intensive, with the release of around 2 tonnes of fossil CO2 per tonne of dense plastic. Energy produced from incineration with energy recovery is also very carbon intensive. It performs best in a minority of cities where all the waste heat is used directly in a district heating network, with an estimated carbon intensity of 368g CO2eq/kWh in EU incinerators, more than GHGs emitted when burning gas (340g CO2eq/kWh), and 24% more than the average carbon intensity of the EU energy grid in 2018 (296g CO2eq/kWh). In most climates and situations, district heating is not needed or available (infrastructure cannot be retrofitted). In those situations, electricity from incinerators with energy recovery has an estimated carbon intensity of 580g CO2eq/kWh in EU	The refrence "Cleaner Earth" and its associated quote has been removed from the revised draft since it is not peer reviewed. Besides, the contribution and negative impact of incineration have been highligthed in the revised draft	Mariel Vilella	Zero Waste Europe/University of Manchester	United Kingdom (of Great Britain and Northern Ireland)
2665	49	1	49	2	I don't buy this statement. This equivalence must depend on the specific process. I don't think that this statement is generally true.	The said statement and its refrence have been removed from the draft since it is not from a peer reviewed source	Jan Wohland	ETH Zurich	Switzerland
17515	49	1	49	2	Can you please qualify this further: "For every ton of waste 1 treated by waste-to-energy plants, 1 ton of GHG is avoided", what are the GHGs, which metric used? There must be some uncertaitnties	This statement has been removed from the revised draft, since it is not from a peer reviewed source.	Alaa Al Khourdajie	IPCC	United Kingdom (of Great Britain and Northern Ireland)
79665	49	2			1 ton of GHG: it covers both methane and carbon dioxide. Repartition could be interesting to evaluate climante benefit.	This statement has been removed from the revised draft, since it is not from a peer reviewed source.	Marc Daras	CentraleSupelecAlumni	France
79667	49	2			Insert at the beginning of second sentence "In case of in biogaz production, the by-product…" since before and after the discussion runs on incineration.	This statement has been revised.	Marc Daras	CentraleSupelecAlumni	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
43191	49	4	49	4	Incineration technology can minimise water and soil pollution (Gu et al. 2019). Other references show that incineration technology is very polluting which should be included and discussed. The text should include a reference to the air pollution related to waste incineration. In the first place, waste incineration is known to produce toxic air pollution (fly ash) and toxic ashes (bottom ashes) - 1 ton of MSW produces approximately 0.3 ton of incinerator bottom ash (IBA). Qiao, X. C., et al. "Production of lightweight concrete using incinerator bottom ash." Construction and Building Materials 22.4 (2008): 473-480. These are inevitable byproducts of the waste-to-energy incineration process which should be recognised and included in the text. In the second place, despite regulations and monitoring (which vary in different regions and countries with different levels of efficiency), incinerators continue producing pollution above the recommended levels for public health safety.	Incineration indeed has negative impact as far as air pollutants are concerned and this has been highlighted in the revised draft. It should be noted that despite its negative impact in terms of releasing air pollutant, inicnreation reduces the voulume and mass of waste, which prevents considerable amount of wastes such as plastics from polluting the land and water bodies. Therefore, the statement that incineration technology minimizes water and soil pollution is true and backed by scientific reference.	Mariel Vilella	Zero Waste Europe/University of Manchester	United Kingdom (of Great Britain and Northern Ireland)
43887	49	4	49	6	One of the hurdles of waste-to-energy (WTE) deployment has something to do with the implemented policies and regulations on a specific country or region. In the case of the Philippines, WTE is being protested by environmental groups because existing Philippine laws (Clean Air Act of 1999) prohibit the use of such technology (specifically incineration). Policies must be, at the very least tailored, to allow the deployment of WTE technologies with specific guidelines focused on mitigating emissions which may have adverse effects on the environment.	Yes that's very true.We have highlited public perception and opposition of WTE such as incineration. As suggested by the reviewer we have stated that policies should be put in place for successful deployment of WTE, which could have adverse effect on the environment.	Vince Davidson Pacañot	University of the Philippines Diliman	Philippines
61987	49	5	49	5	Typo: change "dust, and gases such as SO2, HCI, HF," to "dust, and gases such as SO2, HCL, HF," (note L in HCl not capital i)	Accepted	Esa Vakkilainen	LUT University, Lappeenranta	Finland
61989	49	6	49	6	Typo: change reference "environment (Dieter Mutz Christoph Hugi, Thomas Gross 2017)." to correspond used style of referencing "environment (Mutz et al. 2017)."	Accepted	Esa Vakkilainen	LUT University, Lappeenranta	Finland
43195	49	7	49	8	It should be specified what concrete technology is referring to.	Specific WTE technologies have been highlited in the revised draft	Mariel Vilella	Zero Waste Europe/University of Manchester	United Kingdom (of Great Britain and Northern Ireland)
84483	49	7	49	8	The related statement appears to be based on the literature review of the cited study. The study itself is based on a comparison of 5 waste to electricity technologies that also distinguishes investment and operation costs.	The said statement has been replaced by a more advanced one that represent the whole WTE industry	Siir KILKIS	The Scientific and Technological Research Council of Turkey	Turkey
43197	49	8	49	9	The benefits referred to here are not explained, described or even offer any quote, therefore this evaluation should be deleted. Moreover, there as mentioned previously, no general statements should be attributed to WTE, as this is an umbrella that covers different technologies with very different results. In the case of waste to energy incineration, pyrolisis and gasification, these are shown to be net contributors to climate change, rather than mitigation options. But Anaerobic Digestion, using biodegradable waste, can be an effective climate mitigation option. These differences need to be explained.	In the revised version we have specified the WTE technologies	Mariel Vilella	Zero Waste Europe/University of Manchester	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
43199	49	11	49	13	The text needs to specify that it refers to thermal WTE (including incineration, gasification and pirolisys). Moreover, it needs adding and quoting that concerns about its pollution generation is still prevalent despite the state-of-the art pollution control devices. "Furthermore, despite the sharp development of pollution control systems, this technique is still not widely accepted due to concern for toxic metals that may concentrate in ash; emission of solid particulate material, SOx, NOx, chlorinated compounds such as HCl and dioxins [18, 19]. Thanopoulos, S., Karellas, S., Kavrakos, M., Konstantellos, G., Tzempelikos, D., & Kourkoumpas, D. (2020). Analysis of Alternative MSW Treatment Technologies with the Aim of Energy Recovery in the Municipality of Vari-Voula-Vouliagmeni. Waste and Biomass Valorization, 11(4), 1585-1601. https://link-springer-com.manchester.idm.oclc.org/article/10.1007/s12649-018-0388-5	We have specified incineration as the type of WTE referred to in the statement. Also, the negative impact of incineration has been highlited in the revised draft	Mariel Vilella	Zero Waste Europe/University of Manchester	United Kingdom (of Great Britain and Northern Ireland)
28619	49	13	49	13	including CCS, see IEAGHG (2020) "CCS on Waste to Energy", IEAGHG 2020-06	We have highlited the benefits of the integration of CCS and WTE in the revised draft	Tim Dixon	IEAGHG	United Kingdom (of Great Britain and Northern Ireland)
17377	49	14	49	14	Chapters 6.4.3 and 6.4.4 are mainly relevant for wind and solar, where integration into exsiting systems is very difficult for high penetrations of wind and solar, and where large amounts of electricity storage are required. In my opinion, these topics should be covered as sub-chapters of wind and solar energy chapters.	Structure would not change and is appropriate.	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
30725	49	14	49	36	In 6.4.3 Systems and System Integration, it is not mentioned about the increase in system cost due to the expantion of VRE. The increase in cost due to the expantion of the share of VRE could also be shared from the referenece such as below. https://www.oecd-nea.org/upload/docs/application/pdf/2019-12/7299-system-costs.pdf	The following has been added:"In summary, the key concern is that deployment of VREs and decarbonisation of energy demand (e.g. heat and transport sectors), will significantly increase energy infrastructure investment as well as system balancing costs (NEA 2019, Poyry and Imperial College 2017)."	Government of Japan	Climate Change Division - Ministry of Foreign Affairs	Japan
33059	49	14	49	14	the emphasize of integrating different energy crears such as electircity, heating, cooling and gas needs to be highlighted more. Energy systems integration and integrated energy network accelerate the energy transition. When fluctuating renewable energy soutces are takingover, the gas, heating and cooling and transport infrastructures would be able to provide the required felexibility. interations between the major energy networks (electricity, heating and gas) should be further exploited to provide flexible solutions.	Noted. The topic is interesting and important. However, space limits prevent us from addressing it here	Yashar Hajimolana	University of Twente	Netherlands
1075	49	15			what 'GHG emissions are emitted across the economy'?	Fixed	Alok Dhaundiyal	Szent Istvan University	Hungary
4117	49	15	49	15	"GHG emissions are emitted across the economy." The word "emissions" is redundant.	Fixed	Tatsuki Ueda	National Agriculture and Food Research Organization	Japan

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
48127	49	16	49	19	"Research indicates that flexibility technologies and advanced control of integrated energy systems – for example infrastructures of electricity, heating/cooling, gas/hydrogen, transport sectors – could reduce energy investment and network infrastructure investments by more than 20%." This was shown first for the world in Jacobson, M.Z., and M.A. Delucchi, A path to sustainable energy by 2030, Scientific American, November 2009 and in more detail for 143 countries in Jacobson, M.Z., M.A. Delucchi, M.A. Cameron, S.J. Coughlin, C. Hay, I.P. Managaran, Y. Shu, and A.-K. von Krauland, Impacts of Green New Deal energy plans on grid stability, costs, jobs, health, and climate in 143 countries, One Earth, 1, 449-463, doi:10.1016/j.oneear.2019.12.003, 2019. Please include	Taken into account. The sentence is updated and new refernces are added:"Analysis highlights that flexibility technologies and advanced control of integrated energy systems (e.g. considering the interaction between electricity, heating/cooling, gas/hydrogen, transport sectors), could reduce energy infrastructure investments by more than 20% in future low-carbon energy systems (Strbac et al. 2015a; Jacobson et al. 2019; Carbon Trust 2021)."	Mark Jacobson	Stanford University	United States of America
52207	49	16	49	16	"System of systems" is not developed in this chapter; in fact the notion of an energy system is insufficiently developed.	Rejected. The focus of this section is on a approach in which Different energy sectors are fully integrated. The title is changed to "energy system integration"	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
2843	49	17	49	20	Also, the reuse of waste streams such as industrial waste heat and bio-waste for energy purposes could increase the overall efficiency ad circularity of the energy system and should be encouraged.	Rejected. The topic is interesting and important. However, space limits prevent us from addressing it here	Leonardo Barreto	Head of center "EU&International"	Austria
20433	49	21	49	22	Can you clarify what "a transition to digitalisation-based control paradigm" means and what relevance it has to systems integration. This is not clear to the reader.	Taken into account. The sentence is updated and new references are added:"The electricity grid will serve as a backbone of future low-carbon energy systems, including transition to digitalization-based control paradigm, which will facilitate radical changes in the delivery of security of supply from redundancy in assets – the traditional approach – to a smart control paradigm, given the rapid development of advanced control and communication systems, which would reduce the system investment and operation costs significantly (Strbac et al. 2018; Münster et al. 2020; Bérut, A et al., 2012; Lent, C et al., 2018). "	Tommi Ekholm	Finnish Meteorological Institute	Finland
55731	49	21	49	22	Is this a major conclusion? Add a confidence assessment and offset as such.	The sentence is updated and new references are added:"The electricity grid will serve as a backbone of future low-carbon energy systems, including transition to digitalization-based control paradigm, which will facilitate radical changes in the delivery of security of supply from redundancy in assets – the traditional approach – to a smart control paradigm, given the rapid development of advanced control and communication systems, which would reduce the system investment and operation costs significantly (Strbac et al. 2018; Münster et al. 2020; Bérut, A et al., 2012; Lent, C et al., 2018). "	Government of United States of America	U.S. Department of State	United States of America
71603	49	21	49	21	All focus only on electricity. The number 13 GW is for electricity, but waste to energy also produce thermal energy which makes big share, so please consider to provide numbers on thermal energy.	Rejected. The 13 GW was not found in the text.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
84337	49	21	49	21	Besides the tension on functional and structural material, the issue of digitalization is probably the bigger long-term uncertainty in term of energy either to supply demand-side (as described in chapter 5), or to manage the energy system by itself with more intermittent sources, more connectivity, more electric and dispersed sources, less elastic/analogic loads, more (versatile) end-uses by migration towards carbon-free sources. However, the specificity of the power system is to balance (i) the energy flowing from the supply- to the demand-side, and (ii) the energy dedicated to its control (including digitalization) and its stability under operation (ancillary services), both of them sharing the same physical system. Under the trend of a higher connectivity, the power system requires a higher redundency and a higher level of resilience, each of them contributing to reinforce, in a pace growing faster than the number of connections, the weight of digitalization and energy self-consumption of the ancillary services in the future. Basically, the second principle of thermodynamics requires to spend an amount of energy to manipulate information. This value was assessed by Landauer [see e.g.: A. Berut, A. Arakelyan, A. Petrosyan, S. Ciliberto, R. Dillenschneider, E. Lutz: Experimental verification of Landauer's principle linking information and thermodynamics, Nature, 483, pp. 187-192, 2012; N. Gershenfeld: Signal entropy and the thermodynamics of computation, IBM Systems Journal, 35, (3&4), pp.577-586, 1996; and: Energy Limits in Computations, Edited by : Lent, Orlov, Porod, Snider, Springer, 2019]. As matter of fact, current technologies (Random Access Memory, Phase Change Memory) require at least 6 orders of magnitude more to perform the binary operation of Landauer [R. Landauer, "Irreversibility and Heat Generation in the Computing Process," IBM Journal of Research and Development 5, No. 3, 183–191 (1961)] and a technological breakthrough is mandatory in order reduce it drastically by shifting from polarized technologies (with permanent leakage currents) to spintronics... or quantum computing for distant time-horizon.	Taekn into account. The following references are added based on your suggestion: Bérut, A et al., 2012; Lent, C et al., 2018. The sentence is updated and new references are added:"The electricity grid will serve as a backbone of future low-carbon energy systems, including transition to digitalization-based control paradigm, which will facilitate radical changes in the delivery of security of supply from redundancy in assets – the traditional approach – to a smart control paradigm, given the rapid development of advanced control and communication systems, which would reduce the system investment and operation costs significantly (Strbac et al. 2018; Münster et al. 2020; Bérut, A et al., 2012; Lent, C et al., 2018). " The topic is interesting and important, however, due to space limits we were not able to expand further.	Vincent MAZAURIC	Schneider Electric	France
2669	49	24	49	26	The balance also needs to maintained for timescales exceeding one year. "At timescales including annual …" would be more correct in my view.	Taken into account. The sentence is updated:"This will present a challenge because the balance between demand supply needs to be maintained at timescales from sub-seconds, days, seasons to multiple years"	Jan Wohland	ETH Zurich	Switzerland
10941	49	25	49	25	between demand supply needs ?	Fixed	Dong-Woon NOH	Korea Energy Economics Institute	Republic of Korea
16365	49	25	49	25	between demand supply needs ?	Fixed	Government of Republic of Korea	Korea Meteorological Administration (KMA)	Republic of Korea
37691	49	25	49	26	It should be stated upfrongt that storage for timescales needed to balance annual or seasonal demand is a challenge.	Taken into account. For this purpose hydrogen storage is considered as a solution for long-duration of energy storage. The sentece is updated:"Hydrogen production processes (power-to-gas and vice versa) and hydrogen storage can support short-term and long-term balancing in the electricity system and enhance resilience (Stephen and Pierluigi 2016; Strbac et al. 2020). "	Ravi B Grover	Homi Bhabha National Institute	India
73953	49	27	49	27	"greater frequency regulation" is vague… instead: "advanced frequency regulation approaches (e.g. based on synthetic inertia)"	updated	Heleno Miguel	Lawrence Berkeley National Laboratory	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
69567	49	29	49	32	Unclear in what sense this challenge here is distinct from the challenge expressed from line 22 to line 29. Suggests deletion.	Rejected. The previous text is updated to cover also the need of flexibility and this lines are removed instead.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
2839	49	30	49	32	Flexibilty would have to be increased as the share of renewables in the energy system increases. Besides storage, this includes flexible generation (e.g. virtual power plants), demand response and the use of interconnectors to balance demand and supply. Sector coupling between electricity, heat and transport can also provide flexibility opportunities.	Noted. Thanks for the comment. This has been presented in the section and due to space limits, we cannot address it in more detail.	Leonardo Barreto	Head of center "EU&International"	Austria
5361	49	31	49	31	replace "fossil fueled " by "thermal", in order to include nuclear production.	Fixed	Michel SIMON	Retraité/ Pdt d'association	France
37693	49	31	49	32	It should be stated upfrongt that storage for timescales needed to balance annual or seasonal demand is a challenge.	Taken into account. For this purpose hydrogen storage is considered as a solution for long-duration of energy storage. The sentece is updated:"Hydrogen production processes (power-to-gas and vice versa) and hydrogen storage can support short-term and long-term balancing in the electricity system and enhance resilience (Stephen and Pierluigi 2016; Strbac et al. 2020). "	Ravi B Grover	Homi Bhabha National Institute	India
2667	49	32	49	34	Where is the evidence to back this claim? This strongly depends on the specifics of how the sectors are coupled. This sentence also conflicts with conclusions in other paragraphs, for example in the next subsection: "Hydrogen production processes (power-to-gas and vice versa) and hydrogen storage can support short-term and long-term balancing in the electricity system (Stephen and Pierluigi 2016; Strbac et al. 2018). Electrolysis-based production of hydrogen can increase the resilience of electricity systems with high penetration of variable renewable electricity with the support of hydrogen power plants and long-duration hydrogen storage (Strbac et al. 2018). Hybrid heat pumps can provide flexibility to both electricity and gas systems, by switching optimally to heat pumps in off-peak hours and gas boilers in peak hours (Element Energy 2017; Klein et al. 2014; Dengiz et al. 2019; Fischer et al. 2016)."	Taken into account. The paragraph is improved and updated for more clarification:"TThe electricity grid will serve as a backbone of future low-carbon energy systems, including transition to digitalization-based control paradigm, which will facilitate radical changes in the delivery of security of supply from redundancy in assets – the traditional approach – to a smart control paradigm, given the rapid development of advanced control and communication systems, which would reduce the system investment and operation costs significantly (Strbac et al. 2018; Münster et al. 2020; Bérut, A et al., 2012; Lent, C et al., 2018). There are two key challenges: (i) integration of large amounts of variable renewable electricity (VRE) technologies (Hansen et al. 2019), particularly wind and solar generation (Perez et al. 2019; Bistline et al. 2019). This will present a challenge because the balance between demand supply needs to be maintained at timescales from sub-seconds, days, seasons to multiple years. Increased renewable shares, which are inverter-based, will reduce system inertia (i.e., by displacing the capacity of thermal generation) (Malekpour et al. 2020). Hence, advanced frequency regulation approaches, and sufficient flexibility technologies such as electricity storage, flexible demand, grid forming converters etc., (Strbac et al. 2015a) would be required, particularly to deal with sudden losses of supply (e.g., as a result of a failure of a large generator or interconnector or a rapid increase in demand) (Teng et al. 2017; Chamorro et al. 2020). Furthermore, (ii) the electrification of segments of the heat and transport sectors	Jan Wohland	ETH Zurich	Switzerland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
69569	49	32	49	34	The opposite may hold true. Electrification of transport sector will largely rest on deploying large fleets of battery electric vehicles, most of them staying iddle most of the day. If recharging is well-managed to avoid peak hours as much as possible, then the electrification of transport will increase peak demand dispropotionnally lower, not higher thant the corresponding increase in energy. Similarly, compact heat storage, already commercial (Siemens, Lumenion, etc.) in molten salts, vulcanic rocks, steel or refractory bricks, can delivery continuous industrial heat (up to 650°C commercial, up to 1600°C under development) as superheated air or steam from few hours of electricity - with storage cost being a fraction of that of electricity storage. Some industries process in batches, and provided prices of electricity duly reflect its costs at the different times of the day and the year, if they get electrify they will be eager to reduce or cut consumption during peak hours. Already some very un-flexible continuous electric load such as aluminum melting have been transformed with heat management to deliver flexibility, increasing consumption when the electricity price is low, reducing it when it's high - equivalent to a large virtual battery (case of Trimet's Aluminium plant in Essen, Germany, see Philibert, C. 2017, Renewable Energy for Industry, IEA Insight paper.) This sentence appears by the way to be contradictory with that in lines 41 to 44 and the entire paragraph on p. 50, lines 1-16.	Taken into account. The paragraph is improved and updated for more clarification:"TThe electricity grid will serve as a backbone of future low-carbon energy systems, including transition to digitalization-based control paradigm, which will facilitate radical changes in the delivery of security of supply from redundancy in assets – the traditional approach – to a smart control paradigm, given the rapid development of advanced control and communication systems, which would reduce the system investment and operation costs significantly (Strbac et al. 2018; Münster et al. 2020; Bérut, A et al., 2012; Lent, C et al., 2018). There are two key challenges: (i) integration of large amounts of variable renewable electricity (VRE) technologies (Hansen et al. 2019), particularly wind and solar generation (Perez et al. 2019; Bistline et al. 2019). This will present a challenge because the balance between demand supply needs to be maintained at timescales from sub-seconds, days, seasons to multiple years. Increased renewable shares, which are inverter-based, will reduce system inertia (i.e., by displacing the capacity of thermal generation) (Malekpour et al. 2020). Hence, advanced frequency regulation approaches, and sufficient flexibility technologies such as electricity storage, flexible demand, grid forming converters etc., (Strbac et al. 2015a) would be required, particularly to deal with sudden losses of supply (e.g., as a result of a failure of a large generator or interconnector or a rapid increase in demand) (Teng et al. 2017; Chamorro et al. 2020). Furthermore, (ii) the electrification of segments of the heat and transport sectors	Cédric PHILIBERT	Institut Français des Relations Internationales	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
73955	49	32	49	34	Electrification of transport and heat will definitely increase the demand. However, there is no evidence (in the references provided) that this increase will be disproportionally higher in the peak demand.	Taken into account. The paragraph is improved and updated for more clarification:"TThe electricity grid will serve as a backbone of future low-carbon energy systems, including transition to digitalization-based control paradigm, which will facilitate radical changes in the delivery of security of supply from redundancy in assets – the traditional approach – to a smart control paradigm, given the rapid development of advanced control and communication systems, which would reduce the system investment and operation costs significantly (Strbac et al. 2018; Münster et al. 2020; Bérut, A et al., 2012; Lent, C et al., 2018). There are two key challenges: (i) integration of large amounts of variable renewable electricity (VRE) technologies (Hansen et al. 2019), particularly wind and solar generation (Perez et al. 2019; Bistline et al. 2019). This will present a challenge because the balance between demand supply needs to be maintained at timescales from sub-seconds, days, seasons to multiple years. Increased renewable shares, which are inverter-based, will reduce system inertia (i.e., by displacing the capacity of thermal generation) (Malekpour et al. 2020). Hence, advanced frequency regulation approaches, and sufficient flexibility technologies such as electricity storage, flexible demand, grid forming converters etc., (Strbac et al. 2015a) would be required, particularly to deal with sudden losses of supply (e.g., as a result of a failure of a large generator or interconnector or a rapid increase in demand) (Teng et al. 2017; Chamorro et al. 2020). Furthermore, (ii) the electrification of segments of the heat and transport sectors	Heleno Miguel	Lawrence Berkeley National Laboratory	United States of America
80469	49	32	49	32	Recent developments suggest that “plug-in” base load replacements for fossil and nuclear power stations are possible with renewable energies, see e.g. https://reneweconomy.com.au/massive-1000mw-baseload-wind-solar-and-hydrogen-plant-pitched-for-nsw-16049/. “Project NEO” targets a 1GW power output using solar, wind and hydrogen and is said to cost AUD 3.5 billion and to be finished in 2027. Even if this about doubles for this first of a kind (FOAK) to US$ 6 billion, it would still be less expensive to build than a new comparable nuclear power station, it is faster to build than that and this concept will benefit from the continuing rapid cost reductions in renewable energies. One possibility to include this development would be inserting the following sentence here: “Potential ways of overcoming these challenges could include building base-load renewable energy power stations as suggested for a 1GWe power plant in Australia (reference).”	Noted. The topic is interesting and important. However, space limits prevent us from addressing it here	Moritz Riede	University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
84339	49	32	49	36	The question of migration towards electricity addresses the issue of tension on functional/structural materials.	Rejected. This comment seems not to be relevant to system perspectives	Vincent MAZAURIC	Schneider Electric	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
1563	49	33	49	34	"the electrification of segments of the heat and transport sectors represents a major challenge as the increase in peak demand would be disproportionally higher than the corresponding increase in energy." This statement would conflict with many studies that see EVs as providing a way of moderating peak demand through the accessible storage provided.	Taken into account. The sentence is updated:"Furthermore, (ii) the electrification of segments of the heat and transport sectors represents a major challenge as the increase in peak demand would be disproportionally higher than the corresponding increase in energy. Surges in peak demand may require very significant reinforcement of generation and network infrastructures if the historical passive system operation paradigm is maintained (Vivid Economics, 2019). "	Martin Green	UNSW Sydney	Australia
2841	49	33	49	36	At the same time, sector coupling involving the electrification of heating and cooling in buidlings, transport (e-mobility) and industry can provide potential to increase the flexibility of the energy system	Taken into account. This is mentioned in the previous paragraph:"Analysis highlights that flexibility technologies and advanced control of integrated energy systems (e.g. considering the interaction between electricity, heating/cooling, gas/hydrogen, transport sectors), could reduce energy infrastructure investments by more than 20% in future low-carbon energy systems (Strbac et al. 2015a; Jacobson et al. 2019; Carbon Trust 2021)."	Leonardo Barreto	Head of center "EU&International"	Austria
71605	49	35	49	36	Peak demand must not be higher than increase in energy demand	Taken into account. The sentence is updated:"Furthermore, (ii) the electrification of segments of the heat and transport sectors represents a major challenge as the increase in peak demand would be disproportionally higher than the corresponding increase in energy. Surges in peak demand may require very significant reinforcement of generation and network infrastructures if the historical passive system operation paradigm is maintained (Vivid Economics, 2019). "	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
47181	49	37	51	3	Challenges for integrated planning, implementation barriers are not sufficiently presented and discussed. There is no real evaluation of resilience (distributed and renewable energy systems compared to current energy systems).	Noted. The topic is interesting and important. However, space limits prevent us from addressing it here	Stuart Minchin	The Pacific Community	Australia
75853	49	37	51	3	Given that the section focuses on sectoral coupling, I was expecting a broader discussion on hydrogen and the complement to renewable electricity to be able to satisfy demand in the hard-to-abate sectors. If that is done in another chapter of the report, it would be good to make a cross reference	Noted. As you mentioned the topic is interesting and important and we investigated this in a separate section (section 6.4.5). However, space limits prevent us from addressing it here as well.	Herib Blanco	International Renewable Energy Agency (IRENA)	Germany

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
64253	49	38	49	47	Sorry, the wording “relatively inflexible nuclear power” is misleading and should be corrected. In some countries, nuclear power plants are operated in a more flexible way for instance through load following and frequency control (1) (2) (3). References (1) IAEA (2018), Non-baseload Operations in Nuclear Power Plants: Load Following and Frequency Control Flexible Operations, - https://www-pub.iaea.org/books/iaeabooks/11104/Non-baseload-Operation-in-Nuclear-Power-PlantsLoad-Following-and-Frequency-Control-Modes-of-Flexible-Operation (2) In addition, flexibility in electricity generation from nuclear can be enhanced by the development of small modular reactors (SMRs). Small Modular Reactors (SMRs) are defined as reactors with an electrical output lower than 300 MWe. SMRs have been first considered by the nuclear industry for commercial deployments with the aim to ensure the supply of energy to communities with little access to other sources or to address the difficulties of financing a large nuclear power plant. Nevertheless, in recent years, with large new nuclear projects advancing slowly, an increased presence of variable sources in the energy mix and the progressive decentralization of the grid, opportunities in smaller scale nuclear power reactors have become again under analysis. In SMRs design, attention is paid in particular to the capacity of the reactor to rapidly respond to the changes in the required power output. (3) FTI Energy (2018), Pathways to 2050: role of nuclear in a low-carbon Europe, https://www.foratom.org/2018-11-22_FTI-CLEnergy_Pathways2050.pdf	Taken into account. Inflexible nuclear is removed and the role for nuclear is updated and clarified in flexbile/dispachable generation section:"In terms of nuclear generation, there is already some important development in making nuclear plants more flexible (e.g., in France (Office of Nuclear Energy, 2021)). Furthermore, development of small modular reactors could also support system balancing (FTI Cons. LLP., 2018). "	Georges VAN GOETHEM	Royal Academy of Overseas Sciences (ARSOM - KAOW)	Belgium
76407	49	38	49	44	Future nuclear powered grids will provide reliable flexible energy at a much lower cost and with lower emissions than a system reliant upon VRE and storage.. Nuclear energy provides a low carbon system with elegant simplicity. Trying ti integrate VRE is a retrograde step bothe environmentally and economically. Hydrogen production has been identified in the Lucid Catalyst "Energy Options Network" paper to be lower cost when generated by nuclear energy in part because the capacity factor of the electrolysers will be higher with more reliable energy availability.	Taken into account. Inflexible nuclear is removed and the role for nuclear is updated and clarified in flexbile/dispachable generation section:"In terms of nuclear generation, there is already some important development in making nuclear plants more flexible (e.g., in France (Office of Nuclear Energy, 2021)). Furthermore, development of small modular reactors could also support system balancing (FTI Cons. LLP., 2018). "	Robert Parker	Nuclear for Climate Australia	Australia
78627	49	38	49	44	the statement is strongly supported by Bogdanov et al. (2021) - https://www.sciencedirect.com/science/article/pii/S0306261920316639 - in that article the cross-sector coupling is analysed in detail in a step-by-step approach for the sectors power, heat, transport, industry and desalination, fully supporting the statement	Taken into account. The reference is added:"At the same time, the huge latent flexibility hidden in other energy sectors – for example, heating and cooling, hydrogen, transport, and gas systems – provides opportunities to take advantage of synergies and coordinate operation across energy sectors (Ceseña et al. 2019, Zhang et al. 2018; Bogdanov et al., 2021; Pavičević et al., 2020; Robinus et al. 2017, Carbon Trust 2021). "	Christian Breyer	LUT University	Finland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
4833	49	39	49	40	“The lack of flexibility in the current electricity system fundamentally limits high penetration of variable renewable electricity, as well as relatively inflexible nuclear power.” This strong position is not based on the full literature. IPCC (2011) SRREN concludes that all energy demand can be met by renewable energy. There are no “fundamental limits” to a “high penetration of variable renewable electricity”. This is also stated at other places in chapter 6, such as Box 6.6. "Relatively (?) inflexible nuclear power" is unsuited for matching variable renewable power, because the two inflexible options request priority treatment over the other. Priority is needed for keeping the own load factors intact, i.e., the profitability of the own investments (Haas et al. 2019; Verbruggen 2008).	Taken into account. Inflexible nuclear is removed and the role for nuclear is updated and clarified in flexbile/dispachable generation section:"In terms of nuclear generation, there is already some important development in making nuclear plants more flexible (e.g., in France (Office of Nuclear Energy, 2021)). Furthermore, development of small modular reactors could also support system balancing (FTI Cons. LLP., 2018). "	Aviel Verbruggen	University of Antwerp	Belgium
24677	49	39	49	40	Despite a broad perception that nuclear power plants are inflexible baseload sources, fact is that nuclear power can also provide large scale solutions to answer the request for flexibility and network stability in some Member States. Technically, existing nuclear power plants (NPPs) and new designs can perform both frequency control and load-following operations. Flexible operations of NPPs depend on: - The applicable regulatory framework which may vary from one Member States to another - The commercial decision of the operator considering the market environment Useful references: - Load-following operating mode at Nuclear Power Plants (NPPs) and incidence on Operation and Maintenance (O&M) costs. Compatibility with wind power variability, C. Bruynooghe, A. Eriksson, G. Fulli, 2010 - Nuclear Energy Factsheets: Load following capabilities of Nuclear Power Plants, SNETP, 2017	Taken into account. Inflexible nuclear is removed and the role for nuclear is updated and clarified in flexbile/dispachable generation section:"In terms of nuclear generation, there is already some important development in making nuclear plants more flexible (e.g., in France (Office of Nuclear Energy, 2021)). Furthermore, development of small modular reactors could also support system balancing (FTI Cons. LLP., 2018). "	Ann Jessica Johnson	FORATOM (European Atomic Forum)	Belgium
37695	49	39	49	40	The problem is created by intermittent nature of solar and wind and not by any other technology. This aspect needs correction.	Taken into account. Inflexible nuclear is removed and the role for nuclear is updated and clarified in flexbile/dispachable generation section:"In terms of nuclear generation, there is already some important development in making nuclear plants more flexible (e.g., in France (Office of Nuclear Energy, 2021)). Furthermore, development of small modular reactors could also support system balancing (FTI Cons. LLP., 2018). "	Ravi B Grover	Homi Bhabha National Institute	India
55733	49	39	49	39	This implies all systems globally are "the". Caveat appropriately, especially given that many systems can accommodate high VRE (Ireland, Australia, example days/experiences in Portugal, UK, etc.).	Taken into account. Thanks for the comment. "the current electricity system" is replaced by "current electricity systems"	Government of United States of America	U.S. Department of State	United States of America
55735	49	39	49	40	The inclusion of nuclear power in this sentence needs to be further explained. Relatively inflexible nuclear power would contribute to the overall lack of flexibility in the electricity system, but how does a lack of flexibility impact nuclear power?	Taken into account. Inflexible nuclear is removed and the role for nuclear is updated and clarified in flexbile/dispachable generation section:"In terms of nuclear generation, there is already some important development in making nuclear plants more flexible (e.g., in France (Office of Nuclear Energy, 2021)). Furthermore, development of small modular reactors could also support system balancing (FTI Cons. LLP., 2018). "	Government of United States of America	U.S. Department of State	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
55737	49	39	49	40	With respect to nuclear power, this statement is simply false. Nuclear power can be designed and operated in flexible modes. See https://www.sciencedirect.com/science/article/abs/pii/S0306261918303180 The following OECD document describes how in France normal ramping of nuclear plants is < 1.5 % per minute, but some plants ramp at between 2 and 5% of capacity per minute. In any case, going from full to half capacity in an hour is within today's design capability. Because of high capital costs, there are economic incentives to run at high capacity factors but there is no real technical limit to ramping on the hourly time scale. There is an issue with minimum output, which again today's plants have not been designed to have a low Pmin, but there is nothing in principal precluding such designs. See https://www.oecd-nea.org/ndd/reports/2011/load-following-npp.pdf	Taken into account. Inflexible nuclear is removed and the role for nuclear is updated and clarified in flexbile/dispachable generation section:"In terms of nuclear generation, there is already some important development in making nuclear plants more flexible (e.g., in France (Office of Nuclear Energy, 2021)). Furthermore, development of small modular reactors could also support system balancing (FTI Cons. LLP., 2018). "	Government of United States of America	U.S. Department of State	United States of America
61795	49	39	49	40	"The lack of flexibility in the current electricity system fundamentally limits high penetration of variable renewable electricity, as well as relatively inflexible nuclear power". This is an incorrect statement and needlessly mentions nuclear power, as even Gen II nuclear has relatively good flexibility characteristics (see e.g. Figures E.1 and E.2 in (NEA (2011), Technical and Economic Aspects of Load-following with Nuclear Power Plants, OECD/NEA, https://www.oecd-nea.org/ndd/reports/2011/load-following-npp.pdf). The fundamental limiting factor for high share of variable renewable electricity is due to their variable nature and inability to meet society's demand – if wind and solar were dispatchable and reliable, the rest of the power system would not need any more flexibility than it already has. France operates a grid with a 75% nuclear with no issues and very low overall cost. In Germany, existing nuclear plants routinely do load-following to enable a higher penetration of variable renewables.	Taken into account. Inflexible nuclear is removed and the role for nuclear is updated and clarified in flexbile/dispachable generation section:"In terms of nuclear generation, there is already some important development in making nuclear plants more flexible (e.g., in France (Office of Nuclear Energy, 2021)). Furthermore, development of small modular reactors could also support system balancing (FTI Cons. LLP., 2018). "	Rauli Partanen	Think Atom	Finland
63657	49	39	49	40	We suggest that this sentence be either removed completely or change substantially as it is incorrect. Contrary to the statement in this section, grids globally today are currently very felxible, mostly due to large percentages of dispatchable fossil fuel generation. Further to this, nuclear power has been shown to be flexible in France with load following capabilities but could also be flexible with the addition of co-generation of auxiliary energy products such as heat and hydrogen. There is a report published by the Clean Energy Ministerial Campaign Flexible Nuclear Campaign for Nuclear-Renewables Integration that goes into detail about the flexibility of Nuclear: (http://www.cleanenergyministerial.org/sites/default/files/2020-10/CEM%20Flexible%20Nuclear%20Energy%20for%20Clean%20Energy%20Systems_0.pdf)	Taken into account. Inflexible nuclear is removed and the role for nuclear is updated and clarified in flexbile/dispachable generation section:"In terms of nuclear generation, there is already some important development in making nuclear plants more flexible (e.g., in France (Office of Nuclear Energy, 2021)). Furthermore, development of small modular reactors could also support system balancing (FTI Cons. LLP., 2018). "	Government of Canada	Environment and Climate Change Canada	Canada
65827	49	39	49	40	"The lack of flexibility in the current electricity system fundamentally limits high penetration of variable renewable electricity, as well as relatively inflexible nuclear power". This is an inccorrect statement. It is the lack of dispatchability of the variable renewables that limits their integration. France has successfully operated their grid with a 75% share of nuclear with no issues in matching both daily and seasonal variation. In Germany, existing nuclear plants have shifted to load following to enable a higher penetration of variable renewables. See, for example, the figures E.1 and E.2 in (NEA (2011), Technical and Economic Aspects of Load-following with Nuclear Power Plants, OECD/NEA, https://www.oecd-nea.org/ndd/reports/2011/load-following-npp.pdf). It is a typical misconception that nuclear power plants could operate only in constant-power baseload-mode and should be corrected in the IPCC report.	Taken into account. Inflexible nuclear is removed and the role for nuclear is updated and clarified in flexbile/dispachable generation section:"In terms of nuclear generation, there is already some important development in making nuclear plants more flexible (e.g., in France (Office of Nuclear Energy, 2021)). Furthermore, development of small modular reactors could also support system balancing (FTI Cons. LLP., 2018). "	Eero Hirvijoki	Aalto University	Finland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
71607	49	39	49	40	Limitation of variable RES are not due to missing flexibility but due to missing support instruments and consideration of environmental costs in energy prices	Noted. In this section we presented the techno-economic aspect of integration of renewables and how we can integrate these sources cost-effectively to the system. Although your point is intersting, however this is out of scope since we are not talking about policy and also space limit, prevents us to expand further.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
78511	49	39	49	40	Delete last part of sentence in line 40. (delete , as well as relatively inflexible nunclear power.) Nuclear power can be flexible (high ramp rates), but is not used for flexibility because it is the cheapest dispachable carbon-free source, therfore other sources like hydro and gas are used for flexibility.	Taken into account. Inflexible nuclear is removed and the role for nuclear is updated and clarified in flexbile/dispachable generation section:"In terms of nuclear generation, there is already some important development in making nuclear plants more flexible (e.g., in France (Office of Nuclear Energy, 2021)). Furthermore, development of small modular reactors could also support system balancing (FTI Cons. LLP., 2018). "	Tomaž Žagar	Faculty for Energy Technology, University of Maribor	Slovenia
84341	49	39	49	40	Why? Is it a technical problem or a market design issue?	Noted. It could be both, as from technical perspectives flexibilities can address the challenges associated with intermittent nature of renewables. Also, a proper market design is required in order to manage the supply-demand balance.	Vincent MAZAURIC	Schneider Electric	France
8923	49	40	49	40	"The lack of flexibility in the current electricity system fundamentally limits high penetration of variable renewable electricity, as well as relatively inflexible nuclear power." This is wrong or misleading. Nuclear can be highly flexible. It is able to manage power ramps of 5% of the nominal power per minute. In France and Belgium, this possibility is largely used, because nuclear is often out of the "base" and because of the rise of the renewables (with priority). Thus, nuclear in the future will be able to give a high flexibility to the grid. The drawback is the loss in the production factor. But capacity markets will help to compensate this kind of effects. See for example: Cany et al. (2018) « Nuclear power supply: Going against the misconceptions. Evidence of nuclear flexibility from the French experience » C. Cany, C.Mansilla, G.Mathonnière, P.da Costa, Energy, Volume 151, 15 May 2018, pp 289-296	Taken into account. The role for nuclear is updated and clarified in two different sections. However, due to the space limit we were unable to expand further:"At present, the lack of flexibility in current electricity systems fundamentally limits cost-effective integration of high penetration of RES and most of the inflexible nuclear plants." and in flexible generation section:"I. In terms of nuclear generation, there is already some important development in making nuclear plants more flexible (e.g., in France (Office of Nuclear Energy, 2021)). Furthermore, development of small modular reactors could also support system balancing (FTI Cons. LLP., 2018). "	Jean-Guy DEVEZEAUX DE LAVERGNE	Université Paris-Dauphine & Société Française d'Energie Nucléaire	France
21007	49	40	49	40	About "[...] inflexible nuclear power.": believe France has demonstrated that nuclear can be made flexible if needed. This is not a characteristic of nuclear power, but rather a choice at current economic conditions. Please consider to remove the end of the sentence: remove "as well as relatively inflexible nuclear power".	Taken into account. Inflexible nuclear is removed and the role for nuclear is updated and clarified in flexbile/dispachable generation section:"In terms of nuclear generation, there is already some important development in making nuclear plants more flexible (e.g., in France (Office of Nuclear Energy, 2021)). Furthermore, development of small modular reactors could also support system balancing (FTI Cons. LLP., 2018). "	Government of France	Ministère de la Transition écologique et solidaire	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
31481	49	40	49	40	Nuclear power plants may operate with load following in order to be a complement to the renewable energies, and when they are not available, in fact in France is the standard way to operate.	Taken into account. Inflexible nuclear is removed and the role for nuclear is updated and clarified in flexbile/dispachable generation section:"In terms of nuclear generation, there is already some important development in making nuclear plants more flexible (e.g., in France (Office of Nuclear Energy, 2021)). Furthermore, development of small modular reactors could also support system balancing (FTI Cons. LLP., 2018). "	Carolina Ahnert	Universidad Politécnica de Madrid	Spain
37209	49	40	49	40	The statement is wrong. In France, NPPs follow load. Moreover, advanced reactors based on SMRs	Taken into account. Inflexible nuclear is removed and the role for nuclear is updated and clarified in flexbile/dispachable generation section:"In terms of nuclear generation, there is already some important development in making nuclear plants more flexible (e.g., in France (Office of Nuclear Energy, 2021)). Furthermore, development of small modular reactors could also support system balancing (FTI Cons. LLP., 2018). "	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37211	49	40	49	40	are designed to operate flexibly without any issue.	Taken into account. Inflexible nuclear is removed and the role for nuclear is updated and clarified in flexbile/dispachable generation section:"In terms of nuclear generation, there is already some important development in making nuclear plants more flexible (e.g., in France (Office of Nuclear Energy, 2021)). Furthermore, development of small modular reactors could also support system balancing (FTI Cons. LLP., 2018). "	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
51123	49	40	49	40	"relatively inflexible nuclear power": this should be rephrased because, as written, it is factually erroneous, as demonstrated by France [2] where its nuclear fleet has been operating in load folling mode since several decades. Indeed, "relative inflexibility" in not a technical characteristic of nuclear power, but rather an operating choice at current economic conditions. Furthermore, the flexibility of nuclear is beneficial to power system operations with renewable energy [1] References: [1] J.D. Jenkins, Z. Zhou, R. Ponciroli, R.B. Vilim, F. Ganda, F. de Sisternes & A. Botterud, The benefits of nuclear flexibility in power system operations with renewable energy, Applied Energy, Volume 222, 2018, Pages 872-884, ISSN 0306-2619, https://doi.org/10.1016/j.apenergy.2018.03.002. [2] Morilhat, Patrick, Stéphane Feutry, Christelle Le Maitre and Jean Melaine Favennec. “Nuclear Power Plant flexibility at EDF.” (2019) https://hal-edf.archives-ouvertes.fr/hal-01977209/document	Taken into account. Inflexible nuclear is removed and the role for nuclear is updated and clarified in flexbile/dispachable generation section:"In terms of nuclear generation, there is already some important development in making nuclear plants more flexible (e.g., in France (Office of Nuclear Energy, 2021)). Furthermore, development of small modular reactors could also support system balancing (FTI Cons. LLP., 2018). "	Eric PROUST	European Nuclear Society (ENS)	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
61991	49	40	49	40	Inflexibility of nuclear energy is a myth "as well as relatively inflexible nuclear power." to "as well as challenge posed when large amounts of carbon free and low production cost energy like nuclear power is produced." Note that nuclear power has high investment cost but low operating cost (like solar and wind). So who should be the one to stop producing when overproduction is a good question that has not been solved. The fact that nuclear as low cost option continues to produce is not because of inflexibility but due to low operating cost. Flexibility of nuclear power can be seen when looking at French or German nuclear plants change their load. see e.g. https://energy-charts.info/charts/power/chart.htm?l=en&c=DE&source=nuclear_unit&week=03 The same inflexibility myth has been debunked in a report from NEA, the United States Department of Energy, Natural Resources Canada, the Ministry of Economy, Trade and Industry of Japan, the United Kingdom Department for Business, Energy, and Industrial Strategy, the International Energy Agency (IAEA) and 22 other organisations titled titled "Flexible Nuclear Energy for Clean Energy Systems" https://www.nrel.gov/docs/fy20osti/77088.pdf. the Table 14 in page 108 shows that Nuclear has qual rampup/down rate than typical coal. The benefits of flexible nuclear have been argued by e.g. Princeton in Jenkins et al.: 2018, The benefits of nuclear flexibility in power system operations with renewable energy. Applied Energy, 222, pp. 872-884. https://www.sciencedirect.com/science/article/abs/pii/S0306261918303180	Taken into account. Inflexible nuclear is removed and the role for nuclear is updated and clarified in flexbile/dispachable generation section:"In terms of nuclear generation, there is already some important development in making nuclear plants more flexible (e.g., in France (Office of Nuclear Energy, 2021)). Furthermore, development of small modular reactors could also support system balancing (FTI Cons. LLP., 2018). "	Esa Vakkilainen	LUT University, Lappeenranta	Finland
82643	49	40	49	40	It is incorrect that nuclear power is relatively inflexible. In fact most nuclear power plants are capable of significant flexible operations and many plants are already configured that way. There is further potential for nuclear plants to take advantage of cogeneration in the future See the Clean Energy Ministerial Report 'Flexible Nuclear Energy for Clean Energy Systems' (https://www.nrel.gov/docs/fy20osti/77088.pdf). "Nuclear energy" should be deleted from this sentence. The potential flexibility of nuclear power plants as a source of flexible generation should be noted here and in 6.4.3.2	Taken into account. Inflexible nuclear is removed and the role for nuclear is updated and clarified in flexbile/dispachable generation section:"In terms of nuclear generation, there is already some important development in making nuclear plants more flexible (e.g., in France (Office of Nuclear Energy, 2021)). Furthermore, development of small modular reactors could also support system balancing (FTI Cons. LLP., 2018). "	Jonathan Cobb	World Nuclear Association	United Kingdom (of Great Britain and Northern Ireland)
28441	49	43	49	44	To underline the importance of sector coupling in fully integrated energy systems. "Flexibilty provided by individual sector-coupling options stacks up in fully integrated systems" Pavičević et al. 2020 DOI:https://doi.org/10.1016/j.apenergy.2020.115100	Taken into account. The following sentence is updated, including the new reference:"At the same time, the huge latent flexibility hidden in other energy sectors – for example, heating and cooling, hydrogen, transport, and gas systems – provides opportunities to take advantage of synergies and coordinate operation across energy sectors (Ceseña et al. 2019, Zhang et al. 2018; Bogdanov et al., 2021; Pavičević et al., 2020; Robinus et al. 2017, Carbon Trust 2021). "	Naud Loomans	Eindhoven University of Technology	Netherlands
45499	49	47	49	47	The reference European Parliament, 2019 is missing in the reference list	Fixed	Kornelis Blok	Delft University of Technology	Netherlands
52209	49	47	49	47	European Parliament is not a scientific reference, which the sentence requires.	In here we wanted to presented a reference from policy perspective.	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
28517	50	1	50	16	This section is interesting, but I wonder why examples given beyond battery storage are focused on hydrogen, while text below shows that there are different competing technologies/solutions to deliver short-term and long-term balancing in the electricity system, with a number of them having the capacity to come at a lower cost than hydrogen-based ones. I recommend to diversify examples here.	Noted. In this section the role of other technologies such as thermal storage, EVs are also explained. Unfortunately, due to space limit we are not able to expand further.	Pierpaolo Cazzola	International Transport Forum	France
48129	50	1	50	11	The following were the first global papers on coupling electricity-transportation-building energy-industry together. Please reference: (1) Jacobson, M.Z., and M.A. Delucchi, A path to sustainable energy by 2030, Scientific American, November 2009; (2) Jacobson, M.Z., and M.A. Delucchi, Providing all global energy with wind, water, and solar power, Part I: Technologies, energy resources, quantities and areas of infrastructure, and materials, Energy Policy, 39, 1154-1169, doi:10.1016/j.enpol.2010.11.040, 2011; (3) Delucchi, M.Z., and M.Z. Jacobson, Providing all global energy with wind, water, and solar power, Part II: Reliability, System and Transmission Costs, and Policies, Energy Policy, 39, 1170-1190, doi:10.1016/j.enpol.2010.11.045, 2011; (4) Jacobson, M.Z., M.A. Delucchi, Z.A.F. Bauer, S.C. Goodman, W.E. Chapman, M.A. Cameron, Alphabetical: C. Bozonnat, L. Chobadi, H.A. Clonts, P. Enevoldsen, J.R. Erwin, S.N. Fobi, O.K. Goldstrom, E.M. Hennessy, J. Liu, J. Lo, C.B. Meyer, S.B. Morris, K.R. Moy, P.L. O'Neill, I. Petkov, S. Redfern, R. Schucker, M.A. Sontag, J. Wang, E. Weiner, A.S. Yachanin, 100% clean and renewable wind, water, and sunlight (WWS) all-sector energy roadmaps for 139 countries of the world, Joule, 1, 108-121, doi:10.1016/j.joule.2017.07.005, 2017; (5) Jacobson, M.Z., M.A. Delucchi, M.A. Cameron, and B.V, Mathiesen, Matching demand with supply at low cost among 139 countries within 20 world regions with 100% intermittent wind, water, and sunlight (WWS) for all purposes, Renewable Energy, 123, 236-248, 2018; (6) Jacobson, M.Z., M.A. Delucchi, M.A. Cameron, S.J. Coughlin, C. Hay, I.P. Manogaran, Y. Shu, and A.-K. von Krauland, Impacts of Green New Deal energy plans on grid stability, costs, jobs, health, and climate in 143 countries, One Earth, 1, 449-463, doi:10.1016/j.oneear.2019.12.003, 2019.	Taken into account. Thanks for the suggestion. The references of the section are updated.	Mark Jacobson	Stanford University	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
84343	50	1	50	16	As explained in (p. 49, line 21) electricity is the backbone of the energy system. Therefore flexibility options cannot jeopardize stability criteria (synchronism and inertia) occuring on short time-scale (ms to 10 sec).	Noted. The comment is not very cloear, however, as mentioned in the text, Flexibilty can also participate in balancing services from sub seconds (such as EV, batteries, DSR) to seasons (hydorgen storage):"An overview of the interaction between different energy vectors including electricity, gas/hydrogen, and thermal systems is presented in Figure 6.17. A cost-effective, multi-system paradigm, requires coordination of operation and design of these systems (European Parliament 2019). Sector coupling can significantly increase system flexibility, driven the interaction between sectors and the application of advanced technologies, which can reduce cost of energy system decarbonization (Bogdanov et al. 2019; Solomon et al. 2018; Clegg and Mancarella 2016; Zhang et al. 2019; Heinen et al. 2016). For example, district heating infrastructure can enable integration of energy sources generating both heat and power, or cooling systems and electrified heating systems in buildings can provide flexibility through preheating and precooling via thermal energy storage (Li, G. et al. 2017; Li, Z. et al. 2016), reducing system operating costs, carbon emissions, and energy system infrastructure capacity requirements. This cross-vector coordination in decarbonization of heat in UK, can reduce the whole energy system cost by £4.5bn/yr (Carbon Trust 2021). System balancing services can be provided by electric vehicles (EVs) based on vehicle-to-grid concepts – through smart control of EV batteries without compromising customers' requirement for transport (Aunedi et al. 2020)." and "Hydrogen production processes (power-to-gas and vice	Vincent MAZAURIC	Schneider Electric	France
83933	50	2	50	2	Asfaw et al should be cited as Solomon et al. Please also correct the reference list as Solomon, A. A., D. Bogdanov, and C. Breyer, 2018: Curtailment-storage-penetration nexus in the energy transition. Appl. Energy, 235, 1351–1368.	Fixed	Solomon Asfaw	LUT University	Finland
4119	50	3	50	6	Fig. 6.17 does not match what is stated in text. The text discusses about heating/cooling in buildings while the figure appears to show energy systems for an entire economy. Besides, the figure seems too simplistic to describe complex web of energy production, transformation, storage and consumption.	Taken into account. The figure is improved/enhanced and the text is improved.	Tatsuki Ueda	National Agriculture and Food Research Organization	Japan
45463	50	3	50	4	Nuclear cogeneration coupled with thermal energy storage (TES) can help to achieve greater flexibility of thermal power. Please see https://doi.org/10.1016/j.energy.2017.04.144 Low-temperature heat from exiting research nuclear reactors can be additionally used in heat pumps. Please see: https://doi.org/10.1051/e3sconf/201911600108	Noted. The topic is interesting and important. However, space limits prevent us from addressing it here	Maciej Lipka	National Centre for Nuclear Research	Poland
7867	50	5	50	5	(Li et al. 2016; Li et al. 2016) -- a repeat?	Noted. There are two different references, which I clarified: Li, G. et al. 2016; Li, Z. et al. 2016	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
28947	50	5	50	5	Reference twice (Li et al. 2016) - remove one	Noted. There are two different references, which I clarified: Li, G. et al. 2016; Li, Z. et al. 2016	Fabian Heymann	INESC TEC	Switzerland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
52211	50	5	50	5	Li reference repeated; second one should be removed	Noted. There are two different references, which I clarified: Li, G. et al. 2016; Li, Z. et al. 2016	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
73957	50	6	50	7	System balancing reserves can be provided by thermal loads too (evidence DOI: 10.1109/TSG.2014.2368360)	Taken into account. The sentence is updated with including thermal loads as well:"Demand-side schemes – including, for example, smart appliances, EVs, building based thermal energy storage (Heleno et al.,2014) – can potentially provide different types of flexibility services across multiple time frames and system sectors. "	Heleno Miguel	Lawrence Berkeley National Laboratory	United States of America
28439	50	8	50	9	Additional source showing the potential of sector coupling between power and transport. Robinus et al. 2017 DOI:10.3390/en10070956	Taken into account. The reference is added:"At the same time, the huge latent flexibility hidden in other energy sectors – for example, heating and cooling, hydrogen, transport, and gas systems – provides opportunities to take advantage of synergies and coordinate operation across energy sectors (Ceseña et al. 2019, Zhang et al. 2018; Bogdanov et al., 2021; Pavičević et al., 2020; Robinus et al. 2017, Carbon Trust 2021)."	Naud Loomans	Eindhoven University of Technology	Netherlands
37697	50	11	50	13	Variability of intermittent sources will influence utilisation of hydrogen electrolysers. If the cost of electrilysers continue to be high, intermittency will still lead to higher costs. This should be appropriately integrated in the report.	Noted. As you mentioned the topic is interesting and important and we investigated this in a hydrogen section. However, space limits prevent us from addressing it here as well.	Ravi B Grover	Homi Bhabha National Institute	India
61797	50	11	50	13	"Electrolysis-based production of hydrogen can increase the resilience of electricity systems with high penetration of variable renewable electricity with the support of hydrogen power plants and long-duration hydrogen storage (Strbac et al. 2018)." This perspective tackles only a small subset of the climate problem and hides the bigger problem. Due to the capital costs of electrolyzers, the cost of hydrogen strongly depends on the capacity factor at which electricity is available, and if electrolyzers are used just a couple hundred hours/year to deal with VRE variability, the cost both remains very high and is essentially an externalized cost of VRE. As we require significant amounts of clean and low-cost hydrogen, dedicated production systems are needed (see LucidCatalyst, 2021, https://www.lucidcatalyst.com/hydrogen-report).	Taken into account. Thanks for this, the sentence is updated to: "Hydrogen production processes (power-to-gas and vice versa) and hydrogen storage can support short-term and long-term balancing in the electricity system and enhance resilience (Stephen and Pierluigi 2016; Strbac et al. 2020)." more details are provided in section 6.4.5	Rauli Partanen	Think Atom	Finland
65829	50	11	50	13	"Electrolysis-based production of hydrogen can increase the resilience of electricity systems with high penetration of variable renewable electricity with the support of hydrogen power plants and long-duration hydrogen storage (Strbac et al. 2018)." This is only partially true and hides the bigger problem. Due to the capital costs of electrolyzers, the cost of hydrogen strongly depends on the capacity factor at which electricity is available. Therefore, producing hydrogen with either nuclear or biomass is economically more efficient than production with variable sources such as solar and wind (Kayfeci et al., 2019, https://doi.org/10.1016/B978-0-12-814853-2.00003-5 ; LucidCatalyst, 2021, https://www.lucidcatalyst.com/hydrogen-report). Revise accordingly.	Taken into account. Thanks for this, the sentence is updated to: "Hydrogen production processes (power-to-gas and vice versa) and hydrogen storage can support short-term and long-term balancing in the electricity system and enhance resilience (Stephen and Pierluigi 2016; Strbac et al. 2020)." more details are provided in section 6.4.5	Eero Hirvijoki	Aalto University	Finland
5363	50	13	50	13	It should be wise to mention that these devlopments thru hydrogen stil request technological improvements to approach an economical viability. Today, all perspectives of development are limited by economical concerns.	Out of scope. This is investigated separately in the hydrogen section (6.4.5)	Michel SIMON	Retraité/ Pdt d'association	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
28949	50	13	50	13	I suggest to add after "...Strbac et al. 2018)." : However, the economic benefit of power-to-gas plants for energy system balancing and storage provision varies strongly based on the locational patterns of renewable generation patterns, storage sites, location of gas and electricity networks as well as tranmission congestion (Refer to: Jentsch, Trost, Sterner (2014): Optimal Use of Power-to-Gas Energy Storage Systems in an 85% Renewable Energy Scenario; Heymann, Bessa (2015): Power-to-Gas potential assessment of Portugal under special consideration of LCOE)	Taken into account. The following is added according to your suggestion: "However, the economic benefits of flexible power-to-gas plants, energy storage etc., in supporting system balancing and network congestion management will depend strongly on the locations of renewable generation, storage sites, gas / hydrogen and electricity networks (Jentsch et al. 2014; Heymann and Bessa 2015; Ameli et al. 2020). "	Fabian Heymann	INESC TEC	Switzerland
1077	50	16	17		quality must be improved	Taken into account. The quality of the figure is significantly improved and the description is modified.	Alok Dhaundiyal	Szent Istvan University	Hungary
15541	50	16	50	21	Add nuclear energy to resources because it could potentially contribute to all of these services.	Taken into account. The quality of the figure is significantly improved and the description is modified.	Vladimir Kucinov	National Research Nuclear University "MEPHI" (Moslow Enginiring Physical Institute)	Russian Federation
64319	50	17	50	21	The reuse of heat (from industry to residential) could be emphasised more.	Taken into account. The quality of the figure is significantly improved and the re-use of heat is added.	Peter North	Imperial College (part-time PhD student) /Calorem Ltd	United Kingdom (of Great Britain and Northern Ireland)
64613	50	17	50	21	Figure 6.17 is confusing and not helpfulat all, for example where it suggests power can only be produced from vRES (?) or liquids (which non-fossils?) and not from fossils!? Please adjust and complete, the current version is inadequate.	Taken into account. The quality of the figure is significantly improved and the description is modified.	Government of Netherlands	Ministry of Economic Affairs and Climate Policy	Netherlands
71609	50	17	50	21	Figure has 3 sections: Transport, Residential and Industry. Actually residential is only one part of overall building stock, so please consider to change "Residential" into "Building stock" or something similar.	Taken into account. The quality of the figure is significantly improved and the description is modified.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
9573	50	18	50	18	in figure 6.17 caption either delete "(" before Münster or add a ")" at the end	Fixed	Jaume Gasia	Jose Antonio Romero Polo SA	Spain
51365	50	18	50	20	In caption define vRES & RES shown in Fig 6.17 as variable and firm renewable energy sources	Taken into account. The quality of the figure is significantly improved and the description is modified.	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
37699	50	22	50	23	Strategic energy system planning is very important. It should be based on technologies deployble today with scope for corrections as any new technology becomes deployable. Not doing so is resulting in loss of reliability, and is impacting affordability. This aspect should be highlighted more and more in the report.	Noted. This topic is covered appropriately, and unfortunately due to space limit we cannot expand further.	Ravi B Grover	Homi Bhabha National Institute	India
63659	50	22	50	31	District heating infrastructure can enable integration of several renewable energy sources generating both heat and power, allowing for greater system flexibility and efficiency	Taken into account. This following sentence is updated:"For example, district heating infrastructure can enable integration of energy sources generating both heat and power, or cooling systems and electrified heating systems in buildings can provide flexibility through preheating and precooling via thermal energy storage (Li, G. et al. 2017; Li, Z. et al. 2016), reducing system operating costs, carbon emissions, and energy system infrastructure capacity requirements. "	Government of Canada	Environment and Climate Change Canada	Canada

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
9575	50	27	50	27	delete "(" before Strbac	Fixed	Jaume Gasia	Jose Antonio Romero Polo SA	Spain
61993	50	27	50	27	Typo: change "(Zhang et al. 2018a; O'Malley et al. 2020a; (Strbac et al. 2020)." to "(Zhang et al. 2018a; O'Malley et al. 2020a; Strbac et al. 2020)." remove excess parentheses	Fixed	Esa Vakkilainen	LUT University, Lappeenranta	Finland
9577	50	30	50	30	delete "(" before Fu	Fixed	Jaume Gasia	Jose Antonio Romero Polo SA	Spain
61995	50	30	30	31	Typo: change "system cost savings (Aunedi et al. 2016; Strbac et al. 2018; Zhang et al. 2018a; Zhang et al. 2019; (Fu et al. 2020)." to "system cost savings (Aunedi et al. 2016; Strbac et al. 2018; Zhang et al. 2018a; Zhang et al. 2019; Fu et al. 2020)." to remove extra parentheses	Fixed	Esa Vakkilainen	LUT University, Lappeenranta	Finland
6045	50				Advanced nuclear can provide direct process heat avoiding losses from conversion to electricity and back to heat (industrial heating, hard to decarbonise, cross sectoral). Also, high temperature coolants can be used for thermal energy storage	Rejected. The topic is interesting and important. However, space limits prevent us from addressing it here. In previous part the role of nuclear in providing flexibility is investigated in detail.	Adam Burak	University of Michigan	United States of America
9579	51	1	51	1	modify "will be provide" by "will provide"	Fixed	Jaume Gasia	Jose Antonio Romero Polo SA	Spain
21009	51	1	51	1	Will provide instead of "will be provide'	Fixed	Government of France	Ministère de la Transition écologique et solidaire	France
28381	51	4	51	5	Is the term Flexibility Technologies a new term or should it be Flexible Technologies?	Rejected. The current version is appropriate.	Sanjay Kuttan	Singapore Maritime Institute	Singapore
1079	51	5			demand-side	Fixed	Alok Dhaundiyal	Szent Istvan University	Hungary
37701	51	5	51	7	Flexibility technologies are needed, but their cost-effectiveness is yet to be proven even on paper. Provide reference to literature as well as real life application in support of this statement.	Taken into account. This has been mentioned couple of times such as in :"Analysis highlights that flexibility technologies and advanced control of integrated energy systems (e.g. considering the interaction between electricity, heating/cooling, gas/hydrogen, transport sectors), could reduce energy infrastructure investments by more than 20% in future low-carbon energy systems (Strbac et al. 2015a; Jacobson et al. 2019; Carbon Trust 2021)."	Ravi B Grover	Homi Bhabha National Institute	India
76409	51	5	51	40	Five tools are outlined to enable VRE to mimic a flexible energy source. They are Flexible generation, Grid forming converters, Interconnection, Demand side response, Energy storage. All of these tools represent "band aids" to a fundamentally flawed concept of energy provision by VRE. With high levels of nuclear energy, none of these costly tools is required. Demand side response in particular is effectively "putting up the white flag" on effective energy provision to industry.	Taken into account. Inflexible nuclear is removed and the role for nuclear is updated and clarified in flexbile/dispachable generation section:"In terms of nuclear generation, there is already some important development in making nuclear plants more flexible (e.g., in France (Office of Nuclear Energy, 2021)). Furthermore, development of small modular reactors could also support system balancing (FTI Cons. LLP., 2018). "	Robert Parker	Nuclear for Climate Australia	Australia
1081	51	6			converters, effectively	Unfortunately this was not found in the text.	Alok Dhaundiyal	Szent Istvan University	Hungary
77367	51	8	51	8	add "and hydropower" between "thermal" and "generation"	Rejected. This sentence is removed due to space limits.	Atle Harby	SINTEF Energy Research	Norway

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
10069	51	14		17	Flexible generation may be very beneficial for countries with a lot of coal power plants serving baseload. It would be great to elaborate this subject a bit more.	Rejected. The topic is interesting and important. However, space limits prevent us from addressing it here. In previous part the role of nuclear in providing flexibility is investigated in detail.	Government of Indonesia	Ministry of Environment and Forestry	Indonesia
10643	51	14	51	17	May I say you write perhaps too quickly and your rereading is certainly not fully efficient.	Taken into account. The text has been improved and revised.	Philippe Waldteufel	CNRS	France
73959	51	14	51	14	change "Flexible generation" to "Dispatchable generation".	Taken into account. Updated to flexible/dispachable	Heleno Miguel	Lawrence Berkeley National Laboratory	United States of America
74783	51	14	51	17	I will suggest that this section should be revised for more coherence	Taken into account. The text has been improved and revised.	Semilore Abikoye	Department of Chemical Engineering, University of Cape Town	South Africa
9581	51	15	51	15	modify "the" by "they"	Fixed	Jaume Gasia	Jose Antonio Romero Polo SA	Spain
10943	51	15	51	15	The can start more quickly- They can?	Fixed	Dong-Woon NOH	Korea Energy Economics Institute	Republic of Korea
16367	51	15	51	15	The can start more quickly- They can?	Fixed	Government of Republic of Korea	Korea Meteorological Administration (KMA)	Republic of Korea
51367	51	15			enhance system flexibility. They can start more	Fixed	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
55739	51	15	51	16	This sentence is confusing. The intent of the sentence is unclear and should be edited for clarity.	Fixed	Government of United States of America	U.S. Department of State	United States of America
10945	51	16	51	16	maker faster output change-make faster output change?	Fixed	Dong-Woon NOH	Korea Energy Economics Institute	Republic of Korea
16369	51	16	51	16	maker faster output change-make faster output change?	Fixed	Government of Republic of Korea	Korea Meteorological Administration (KMA)	Republic of Korea
37703	51	18	51	18	Grid forming converters will have a cost attached.	Taken into account. We appreciate the comment. All introduced options in this section have cost attached.	Ravi B Grover	Homi Bhabha National Institute	India
84345	51	18	51	24	From the stability issue, grid forming converters allow to switch inertia from kinetic energy to electrostatic energy stored in capacitors (to add in the description). However the density expected in capacitance is 3 orders of magnitude lower addressing an Electromagnetic compatibility issue. Besides, grid forming converters do not behave as rotating machine in default regimes.	Taken into account. Thanks for this. The foucs here is on system integration, and due to space limit we are not able to go into technical detail of converters.	Vincent MAZAURIC	Schneider Electric	France
30727	51	23	51	23	It would be better to explain "marginal" more.	Rejected. Unfortunately this was not found in the text.	Government of Japan	Climate Change Division - Ministry of Foreign Affairs	Japan

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
52213	51	27	51	27	"B" is capitalized when it should not be.	Fixed	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
28421	51	29	51	29	Potential sources on this effect (Bhagwat, et al. 2016) DOI: 10.1016/j.jup.2017.03.005 and (Brown, et al. 2018) DOI: 10.1016/j.energy.2018.06.222	Taken into account. The following sentence is updated, including the new reference:"Electricity interconnectors between different regions can facilitate more cost-effective renewable electricity deployment, enabling large-scale sharing of energy, provision of balancing services, and back-up resources, beyond electricity, energy carriers such as ammonia can also be shared through gas/ammonia/hydrogen based interconnections, strengthening temporal coupling of multi-energy sectors in different regions (Bhagwat, et al. 2016, Brown, et al. 2018) "	Naud Loomans	Eindhoven University of Technology	Netherlands
85491	51	29	51	29	One of the best sources on the (large) potential savings of interconnections is (Brown et al. 2018). I would add him here too. (Fun fact: Tom Brown used to work in quantum physics but he says he decided it was a "racket" and wanted to do something useful for the world so now he's making energy models.)	The following sentence is updated, including the new reference:"Electricity interconnectors between different regions can facilitate more cost-effective renewable electricity deployment, enabling large-scale sharing of energy, provision of balancing services, and back-up resources, beyond electricity, energy carriers such as ammonia can also be shared through gas/ammonia/hydrogen based interconnections, strengthening temporal coupling of multi-energy sectors in different regions (Bhagwat, et al. 2016, Brown, et al. 2018) "	Auke Hoekstra	Eindhoven University of Technology	Netherlands
12203	51	30	51	38	With the increased contribution of renewable energy sources in the grid, the need for baseload electricity such as nuclear should be considered a stabilizing factor and not as part of savings in investments. If we factor in EU's ambitions in terms of hydrogen production (10 million tones of green hydrogen every year by 2030), nuclear as a baseload energy source deliveres better ROI for electrolysers and therefore, the need for nuclear capacity will increase. Experts (CNBC report on green hydrogen. Haim Israel, Managing Director of Research, Head of Global Investment BofA securities, source: https://www.youtube.com/watch?v=aYBGSfzaa4c) say that decarbonization is not achievable only through renewable energy which could lead only to 50-60% emissions reduction in the world, since there are downstream industries such as transportation that are still emitting CO2 and cannot be electrified to reduce usage of fossil fuels (diesel, airplane jet fuel, gas to cars, etc). We propose to renounce to the affirmation that smart grid and flexibility technologies can lead to a reduction in the need for baseload energy sources since it creates false expectations for industries and investors.	Taken into account. "inflexible nuclear" is removed and the role for nuclear is updated and clarified in flexbile/dispachable generation section:"In terms of nuclear generation, there is already some important development in making nuclear plants more flexible (e.g., in France (Office of Nuclear Energy, 2021)). Furthermore, development of small modular reactors could also support system balancing (FTI Cons. LLP., 2018). "	Lavinia Rizea	SN Nuclearelectrica SA	Romania
37705	51	30	51	30	Demand side management will inconvenience vulnerable sections of the society particularly women, who will be made to wrok at inconvenient timings.	Yes and no. This all the depends on the contract between customer and system operator.	Ravi B Grover	Homi Bhabha National Institute	India
9583	51	32	51	32	modify "." by "," after "Furthermore"	Fixed	Jaume Gasia	Jose Antonio Romero Polo SA	Spain

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
2671	51	41			There are some claims in 6.4.3.3 and 6.4.3.4 that lack references. For example: - “A fully-intelligent and sophisticated coordination of the multiple systems through digitalisation and smart control will be required to support this paradigm shift” - Due to the expansion of distributed renewable energy resources, peer-to-peer energy trading is expected to be one of the key elements of next-generation power systems. This will provide a number of benefits, including the creation of a competitive energy market, reduced supply interruptions, and an increase in overall power system efficiency. Blockchain-based technologies could facilitate a shift to decentralised energy system control and support public energy trading without sacrificing users’ privacy. - For example, analysis has demonstrated that flexibility technologies and advanced control systems could enable the UK’s low-carbon emission targets by building 14 GW less nuclear or 20 GW less offshore wind generation. Similarly, DAC be used to sequester carbon using excess variable renewable generation, reducing the need for firm low-carbon generation sources and allowing some residual emissions in electricity or other parts of the energy system.	Taken into account. Thanks for this - Proper references are added in different sections.	Jan Wohland	ETH Zurich	Switzerland
64615	51	41	51	41	Section 6.4.3.3 is largely enigmatic, as it fails to explain if and to what extent the digitalized operations can deliver the benefits promised here. It reads like an advertorial brochure from commercial partners than a thorough scientific assessment.	Taken into account. This section has been improved significantly: "Transition to advanced data-driven control of energy system operations (Sun et al. 2019; Cremer et al. 2019) will require progressive information and communication technologies and infrastructure, including the internet, wireless networks, computers, software, middleware, smart sensors and internet of things (IoT) components, and dedicated technological developments (Motlagh 2020). This will raise standardization and cybersecurity issues, given that it can become a single point of failure for the complete system (Financial Times 2021; IEA 2021; ENISA 2013; Chatham House. 2015). Implementing peer-to-peer energy trading based on blockchain is expected to be one of the key elements of next-generation of power system operation (Qui et al. 2021), enabling consumers to drive system operation and future design, that would increase the overall power system efficiency and security of supply, while reducing carbon dioxide emissions without sacrificing users’ privacy (Andoni et al 2019, Ahl et al. 2020). This concept, when deployed with smart contracts, will be suitable for energy systems involving many participants, where a prerequisite is digitalization (e.g., smart meters, end use demand control systems) (Teufel et al. 2019; Juhar et al. 2018)", due to space limit we are not able to extend further.	Government of Netherlands	Ministry of Economic Affairs and Climate Policy	Netherlands

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
74021	51	41	52	20	Here we could mention that digitalisation would provide significant benefits to energy systems in a wide range of sectors. For example, in the area of woody biomass, smart technologies would contribute to addressing both social and technical challenges, including transportation infrastructure, biomass quality management, business model integration (cascading), stakeholder relationship management, and local community revitalization and socioeconomic development. Reference: Ahl, Amanda, Mika Goto, and Masaru Yarime, "Smart Technology Applications in the Woody Biomass Supply Chain: Interview Insights and Potential in Japan," Sustainability Science, 15, 1531–1553 (2020).	Rejected.The topic is interesting and important. However, space limits prevent us from addressing it here. In previous part the role of nuclear in providing flexibility is investigated in detail.	Masaru Yarime	Hong Kong University of Science and Technology	China
2845	51	42	51	46	Digitalisation also offers the potential to increase energy efficiency through a combination of technologies that gather and analyse data and, based on this data analysis, optimise energy use in real time.	Taken into account. The following has been added:"Furthermore, it offers the potential to increase energy efficiency through a combination of technologies that gather and analyze data and consequently optimize energy use in real time (IEA 2019)."	Leonardo Barreto	Head of center "EU&International"	Austria
20435	51	42	51	42	Please state explicitly how "blockchain type technologies" exactly "significantly reduce energy infrastructure investments while enhancing supply security and resilience".. There's no single argument or citation to back up this bold and broad statement, which sounds like just using one buzzword without any context. I understand the part on digital control systems, but that the benefit would specifically arise from blockchains sounds overblown.	Taken into account. This section has been improved significantly: "Transition to advanced data-driven control of energy system operations (Sun et al. 2019; Cremer et al. 2019) will require progressive information and communication technologies and infrastructure, including the internet, wireless networks, computers, software, middleware, smart sensors and internet of things (IoT) components, and dedicated technological developments (Motlagh 2020). This will raise standardization and cybersecurity issues, given that it can become a single point of failure for the complete system (Financial Times 2021; IEA 2021; ENISA 2013; Chatham House. 2015). Implementing peer-to-peer energy trading based on blockchain is expected to be one of the key elements of next-generation of power system operation (Qui et al. 2021), enabling consumers to drive system operation and future design, that would increase the overall power system efficiency and security of supply, while reducing carbon dioxide emissions without sacrificing users' privacy (Andoni et al 2019, Ahl et al. 2020). This concept, when deployed with smart contracts, will be suitable for energy systems involving many participants, where a prerequisite is digitalization (e.g., smart meters, end use demand control systems) (Teufel et al. 2019; Juhar et al. 2018)".	Tommi Ekholm	Finnish Meteorological Institute	Finland
52215	51	42	51	42	"energy system operation paradigm" is awkward phrasing. Fix	Taken into account. paradigm changed to structure.	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
74011	51	42	51	44	There is no evidence for this statement. Up to my knowledge, there is no scientific study that shows the benefit of peer-to-peer markets (including those with block chain technologies) in terms of security of supply, resilience or investments deferral. I suggest the elimination of this paragraph.	Taken into account. This section has been improved significantly: "Transition to advanced data-driven control of energy system operations (Sun et al. 2019; Cremer et al. 2019) will require progressive information and communication technologies and infrastructure, including the internet, wireless networks, computers, software, middleware, smart sensors and internet of things (IoT) components, and dedicated technological developments (Motlagh 2020). This will raise standardization and cybersecurity issues, given that it can become a single point of failure for the complete system (Financial Times 2021; IEA 2021; ENISA 2013; Chatham House. 2015). Implementing peer-to-peer energy trading based on blockchain is expected to be one of the key elements of next-generation of power system operation (Qui et al. 2021), enabling consumers to drive system operation and future design, that would increase the overall power system efficiency and security of supply, while reducing carbon dioxide emissions without sacrificing users' privacy (Andoni et al 2019, Ahl et al. 2020). This concept, when deployed with smart contracts, will be suitable for energy systems involving many participants, where a prerequisite is digitalization (e.g., smart meters, end use demand control systems) (Teufel et al. 2019; Juhar et al. 2018)".	Heleno Miguel	Lawrence Berkeley National Laboratory	United States of America
28951	51	44	51	44	This claim (high confidence) is so far not sustained. Reference missing?	Taken into account. The sentence is updated with refernces:"A digitalized energy system operation structure, including application of blockchain type technologies, will significantly reduce energy infrastructure investments while enhancing supply security and resilience (Andoni et al. 2019, Strbac, et al., 2020) "	Fabian Heymann	INESC TEC	Switzerland
52217	51	45	51	45	"digitalised energy control paradigm" is awkward phrasing. Fix	Taken into account. paradigm changed to structure.	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
73961	52	1	52	8	Apart from the last sentence, this paragraph is vague and full of jargons, without any objective statement of idea. What is the "change of paradigm" in operation and planning of energy systems that will come with the multi-sector integration?	Taken into account. This section is revised and improved.	Heleno Miguel	Lawrence Berkeley National Laboratory	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
52219	52	6	52	6	Not clear on how digitalization will "facilitate radical changes in the security of supply through redundancy in assets". The statement is not well written. Rewrite.	Taken into account. This sentence is removed from this section in the following section is explained properly:"TThe electricity grid will serve as a backbone of future low-carbon energy systems, including transition to digitalization-based control paradigm, which will facilitate radical changes in the delivery of security of supply from redundancy in assets – the traditional approach – to a smart control paradigm, given the rapid development of advanced control and communication systems, which would reduce the system investment and operation costs significantly (Strbac et al. 2018; Münster et al. 2020; Bérut, A et al., 2012; Lent, C et al., 2018). There are two key challenges: (i) integration of large amounts of variable renewable electricity (VRE) technologies (Hansen et al. 2019), particularly wind and solar generation (Perez et al. 2019; Bistline et al. 2019). This will present a challenge because the balance between demand supply needs to be maintained at timescales from sub-seconds, days, seasons to multiple years. Increased renewable shares, which are inverter-based, will reduce system inertia (i.e., by displacing the capacity of thermal generation) (Malekpour et al. 2020). Hence, advanced frequency regulation approaches, and sufficient flexibility technologies such as electricity storage, flexible demand, grid forming converters etc., (Strbac et al. 2015a) would be required, particularly to deal with sudden losses of supply (e.g., as a result of a failure of a large generator or interconnector or a rapid increase in demand) (Teng et al. 2017; Chamorro et al. 2020). Furthermore, (ii) the electrification of segments of the heat and transport sectors	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
2849	52	10	52	13	Interoperability is also an important aspect. Interoperability is critical to enable smart appliances and flexibility sources such as electric vehicles, heat pump and batteries to exchange data with each other and thus facilitate the uptake of new business models related to renewable energy self-consumption and intelligent energy management and demand response services	Rejected. The topic is interesting and important. However, space limits prevent us from addressing it here. In previous part the role of nuclear in providing flexibility is investigated in detail.	Leonardo Barreto	Head of center "EU&International"	Austria

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
73963	52	10	52	20	The positive and negative aspects of decentralized energy control should be posed in a more clear form. On one hand, decentralization requires ICT infrastructure, raises cybersecurity and standardization problems. On the other hand it respects privacy and increases competition.	Taken into account. This section is revised and improved and due to the space limit we are not able to provide more details in this regard:"This sentence is removed from this section in the following section is explained properly:"TThe electricity grid will serve as a backbone of future low-carbon energy systems, including transition to digitalization-based control paradigm, which will facilitate radical changes in the delivery of security of supply from redundancy in assets – the traditional approach – to a smart control paradigm, given the rapid development of advanced control and communication systems, which would reduce the system investment and operation costs significantly (Strbac et al. 2018; Münster et al. 2020; Bérut, A et al., 2012; Lent, C et al., 2018). There are two key challenges: (i) integration of large amounts of variable renewable electricity (VRE) technologies (Hansen et al. 2019), particularly wind and solar generation (Perez et al. 2019; Bistline et al. 2019). This will present a challenge because the balance between demand supply needs to be maintained at timescales from sub-seconds, days, seasons to multiple years. Increased renewable shares, which are inverter-based, will reduce system inertia (i.e., by displacing the capacity of thermal generation) (Malekpour et al. 2020). Hence, advanced frequency regulation approaches, and sufficient flexibility technologies such as electricity storage, flexible demand, grid forming converters etc., (Strbac et al. 2015a) would be required, particularly to deal with sudden losses of supply (e.g., as a result of a failure of a large generator or interconnector or a rapid increase in demand) (Teng et al.	Heleno Miguel	Lawrence Berkeley National Laboratory	United States of America
48741	52	11	52	12	Suggest to change “communication technologies and infrastructure, including the internet, wireless networks, computers, software, middleware and dedicated technological developments.” to “communication technologies and infrastructure, including the internet, wireless networks, computers, software, middleware, smart sensors and IoT components, and dedicated technological developments.” Reason: Smart sensors and Internet of Things components are important infrustructure of energy digitalisation and future grid, suggest to add here.	Taken into account. the sentence is updated.	Qi An	Energy Research Institute, National Development and Reform Commission of China	China

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
80471	52	12	52	13	Cybersecurity issues of the future energy supply system deserve some more detail here, as the digital infrastructure of our energy system has become critical infrastructure and can become a single point of failure for the complete system. For example, the Government Communications Headquarters (GCHQ), UK's intelligence and security organisation, stopped the nationwide roll-out of smart meters in the UK in 2016 (https://www.ft.com/content/ca2d7684-ed15-11e5-bb79-2303682345c8) due to security concerns. The IEA has done some recent work on "cyber resilience" (https://www.iea.org/reports/power-systems-in-transition); the European Union Agency for Network and Information Security (ENISA) has published several reports on this e.g. "Smart Grid Threat Landscape and Good Practice Guide" (https://www.enisa.europa.eu/publications/smart-grid-threat-landscape-and-good-practice-guide) and there is a Chatham House Report on "Cyber Security at Civil Nuclear Facilities Understanding the Risks" (https://www.chathamhouse.org/2015/10/cyber-security-civil-nuclear-facilities-understanding-risks). The minimum paragraph that should go here could be something like the following, though the recommendation would be to get in touch with the authors of these reports and get them to provide a better summary: "Events like the high profile Solarwinds exploit in 2020 and vulnerabilities exploited in Microsoft Exchange servers in early 2021 which allowed attackers to enter the computer networks of ten thousands of companies around the world have raised the concerns of securing the IT infrastructure of the energy system. Securing not only the physical parts of our energy system is becoming more and more important, as the digital infrastructure of our energy system has become critical infrastructure whose failure can affect whole regions similar to a failure in a power line. With the growing amount of connected devices in our energy system, the potential for cyber attacks raise and according to the World Economic Forum cyber attacks count to the top ten global risks in terms of likelihood and impact. This not only means securing power stations like nuclear power stations (https://www.chathamhouse.org/2015/10/cyber-security-civil-	Taken into account. The section is improved and the suggested refrences (Financial Times 2021; IEA 2021; ENISA 2013; Chatham House. 2015) are added:"Transition to advanced data-driven control of energy system operations (Sun et al. 2019; Cremer et al. 2019) will require progressive information and communication technologies and infrastructure, including the internet, wireless networks, computers, software, middleware, smart sensors and internet of things (IoT) components, and dedicated technological developments (Motlagh 2020). This will raise standardization and cybersecurity issues, given that it can become a single point of failure for the complete system (Financial Times 2021; IEA 2021; ENISA 2013; Chatham House. 2015). Implementing peer-to-peer energy trading based on blockchain is expected to be one of the key elements of next-generation of power system operation (Qui et al. 2021), enabling consumers to drive system operation and future design, that would increase the overall power system efficiency and security of supply, while reducing carbon dioxide emissions without sacrificing users' privacy (Andoni et al 2019, Ahl et al. 2020). This concept, when deployed with smart contracts, will be suitable for energy systems involving many participants, where a prerequisite is digitalization (e.g., smart meters, end use demand control systems) (Teufel et al. 2019; Juhar et al. 2018)"	Moritz Riede	University of Oxford	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
2847	52	13	52	14	P2P trading platforms, governing the automated execution and settlement of the transactions, offer a marketplace for prosumers to trade the renewable energy generated at a better price, encouraging the deployment of distributed generation and allowing consumers more freedom of choice regarding their electricity supplier and generation sources to buy from	Taken into account. The section is improved :"Transition to advanced data-driven control of energy system operations (Sun et al. 2019; Cremer et al. 2019) will require progressive information and communication technologies and infrastructure, including the internet, wireless networks, computers, software, middleware, smart sensors and internet of things (IoT) components, and dedicated technological developments (Motlagh 2020). This will raise standardization and cybersecurity issues, given that it can become a single point of failure for the complete system (Financial Times 2021; IEA 2021; ENISA 2013; Chatham House. 2015). Implementing peer-to-peer energy trading based on blockchain is expected to be one of the key elements of next-generation of power system operation (Qui et al. 2021), enabling consumers to drive system operation and future design, that would increase the overall power system efficiency and security of supply, while reducing carbon dioxide emissions without sacrificing users’ privacy (Andoni et al 2019, Ahl et al. 2020). This concept, when deployed with smart contracts, will be suitable for energy systems involving many participants, where a prerequisite is digitalization (e.g., smart meters, end use demand control systems) (Teufel et al. 2019; Juhar et al. 2018)"	Leonardo Barreto	Head of center "EU&International"	Austria
61997	52	13	52	14	Current sentence "Due to the expansion of distributed renewable energy resources, peer-to-peer energy trading is expected to be one of the key elements of next-generation power systems." does not tell the reader that wholesaler to wholesaler market already exists but peer-to-peer market is practically undeveloped. Suggest changing to "Due to the expansion of distributed renewable energy resources, to be implemented peer-to-peer energy trading is expected to be one of the key elements of next-generation power systems."	Taken into account. The section is improved :"Transition to advanced data-driven control of energy system operations (Sun et al. 2019; Cremer et al. 2019) will require progressive information and communication technologies and infrastructure, including the internet, wireless networks, computers, software, middleware, smart sensors and internet of things (IoT) components, and dedicated technological developments (Motlagh 2020). This will raise standardization and cybersecurity issues, given that it can become a single point of failure for the complete system (Financial Times 2021; IEA 2021; ENISA 2013; Chatham House. 2015). Implementing peer-to-peer energy trading based on blockchain is expected to be one of the key elements of next-generation of power system operation (Qui et al. 2021), enabling consumers to drive system operation and future design, that would increase the overall power system efficiency and security of supply, while reducing carbon dioxide emissions without sacrificing users’ privacy (Andoni et al 2019, Ahl et al. 2020). This concept, when deployed with smart contracts, will be suitable for energy systems involving many participants, where a prerequisite is digitalization (e.g., smart meters, end use demand control systems) (Teufel et al. 2019; Juhar et al. 2018)"	Esa Vakkilainen	LUT University, Lappeenranta	Finland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
71611	52	13	52	20	Benefits for peer-to-peer trading are not clear and scientific evidence is missing. Contribution to green house gas reduction is only indirect as large number of small scale generators can be operated already now	Taken into account. The section is improved and new references are added:"Transition to advanced data-driven control of energy system operations (Sun et al. 2019; Cremer et al. 2019) will require progressive information and communication technologies and infrastructure, including the internet, wireless networks, computers, software, middleware, smart sensors and internet of things (IoT) components, and dedicated technological developments (Motlagh 2020). This will raise standardization and cybersecurity issues, given that it can become a single point of failure for the complete system (Financial Times 2021; IEA 2021; ENISA 2013; Chatham House. 2015). Implementing peer-to-peer energy trading based on blockchain is expected to be one of the key elements of next-generation of power system operation (Qui et al. 2021), enabling consumers to drive system operation and future design, that would increase the overall power system efficiency and security of supply, while reducing carbon dioxide emissions without sacrificing users' privacy (Andoni et al 2019, Ahl et al. 2020). This concept, when deployed with smart contracts, will be suitable for energy systems involving many participants, where a prerequisite is digitalization (e.g., smart meters, end use demand control systems) (Teufel et al. 2019; Juhar et al. 2018)"	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
48743	52	16	52	17	Suggest to change “Blockchain-based technologies could facilitate a shift to decentralised energy system control and support public energy trading without sacrificing users’ privacy.” to “Blockchain-based technologies could facilitate a shift to decentralised energy system control and support transparent and trustable public energy trading without sacrificing users’ privacy.” Reason： blockchain application in energy has a large potential for future energy systems and added value on transparency and credence. Suggest adding here for better recognition of energy blockchain's contribution to energy transition in this report. Supporting document: https://www.sciencedirect.com/science/article/pii/S1364032118307184	Taken into account. The section is improved and new references including (Andoni et al. 2019) are added:"Transition to advanced data-driven control of energy system operations (Sun et al. 2019; Cremer et al. 2019) will require progressive information and communication technologies and infrastructure, including the internet, wireless networks, computers, software, middleware, smart sensors and internet of things (IoT) components, and dedicated technological developments (Motlagh 2020). This will raise standardization and cybersecurity issues, given that it can become a single point of failure for the complete system (Financial Times 2021; IEA 2021; ENISA 2013; Chatham House. 2015). Implementing peer-to-peer energy trading based on blockchain is expected to be one of the key elements of next-generation of power system operation (Qui et al. 2021), enabling consumers to drive system operation and future design, that would increase the overall power system efficiency and security of supply, while reducing carbon dioxide emissions without sacrificing users’ privacy (Andoni et al 2019, Ahl et al. 2020). This concept, when deployed with smart contracts, will be suitable for energy systems involving many participants, where a prerequisite is digitalization (e.g., smart meters, end use demand control systems) (Teufel et al. 2019; Juhar et al. 2018)"	Qi An	Energy Research Institute, National Development and Reform Commission of China	China

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
74015	52	16	52	20	We could particularly emphasize here that peer-to-peer energy exchange based on blockchain would contribute to improving energy efficiency by smoothly matching supply and demand, reducing carbon dioixide emissions by incorporating fluctuating electricity produced by photovoltaics, and strengthening the resilience of energy systems by decentralizing energy production and consumption. References: Ahl, Amanda, Masaru Yarime, Mika Goto, Shauhrat Chopra, Manoj Kumar Nallapaneni, Kenji Tanaka, and Daishi Sagawa, "Exploring Blockchain for the Energy Transition: Opportunities and Challenges Based on a Case Study in Japan," Renewable and Sustainable Energy Reviews, 117, 109488 (2020). Ahl, Amanda, Masaru Yarime, Kenji Tanaka, and Daishi Sagawa, "Review of Blockchain-Based Distributed Energy: Implications for Institutional Development," Renewable and Sustainable Energy Reviews, 107, 200-211 (2019).	Taken into account. The section is improved and new references are added:"Transition to advanced data-driven control of energy system operations (Sun et al. 2019; Cremer et al. 2019) will require progressive information and communication technologies and infrastructure, including the internet, wireless networks, computers, software, middleware, smart sensors and internet of things (IoT) components, and dedicated technological developments (Motlagh 2020). This will raise standardization and cybersecurity issues, given that it can become a single point of failure for the complete system (Financial Times 2021; IEA 2021; ENISA 2013; Chatham House. 2015). Implementing peer-to-peer energy trading based on blockchain is expected to be one of the key elements of next-generation of power system operation (Qui et al. 2021), enabling consumers to drive system operation and future design, that would increase the overall power system efficiency and security of supply, while reducing carbon dioxide emissions without sacrificing users' privacy (Andoni et al 2019, Ahl et al. 2020). This concept, when deployed with smart contracts, will be suitable for energy systems involving many participants, where a prerequisite is digitalization (e.g., smart meters, end use demand control systems) (Teufel et al. 2019; Juhar et al. 2018)"	Masaru Yarime	Hong Kong University of Science and Technology	China

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
82645	52	21	53	2	The stated benefits of flexibility are unclear. The bullet point 'Savings in investment in low carbon generation capacity' should also include renewables. Increased flexibility could also reduce need for certain kinds of renewables as well as nuclear and fossil fuels with CCUS. In fact modelling by Sepulveda et al - The Role of Firm Low-Carbon Electricity Resources in Deep Decarbonization of Power Generation (https://www.sciencedirect.com/science/article/pii/S2542435118303866) show that firm low-carbon resources consistently lower decarbonized electricity system costs and that batteries and demand flexibility do not substitute for firm low-carbon resources Secondly, nuclear plants and fossil CCUS plants are sources of potential flexibility as shown in the reference Clean Energy Ministerial Report 'Flexible Nuclear Energy for Clean Energy Systems' (https://www.nrel.gov/docs/fy20osti/77088.pdf). Adding flexibility technologies means adding these generating sources to the mix, especially to replace carbon emitting generating sources. Finally, the recent extreme cold weather events that affected parts of Europe, Japan and especially Texas highlight the severe limitations of storage, demand side response, interconnectors or convertors for ensuring electricity supply during a crisis. The lessons of these events are still being processed but it seems problematic to recommend flexibility as reducing the need for investment in firm low carbon generation, back-up capacity and electricity network reinficement. Some acknowledgement of climate adaptation and the impacts of extreme weather events is needed	Taken into account. Thanks for this.The bullet point is updated to " Savings in investment in low carbon/renewable generation capacity" /"inflexible nuclear" is removed and the role for nuclear is updated and clarified in flexbile/dispachable generation section:"In terms of nuclear generation, there is already some important development in making nuclear plants more flexible (e.g., in France (Office of Nuclear Energy, 2021)). Furthermore, development of small modular reactors could also support system balancing (FTI Cons. LLP., 2018). "/ Furthermore, we presented how flexibility (hydrogen stoarge) can be beneficial in extreme weather conditions:" Hydrogen production processes (power-to-gas and vice versa) and hydrogen storage can support short-term and long-term balancing in the electricity system and enhance resilience (Stephen and Pierluigi 2016; Strbac et al. 2020). However, the economic benefits of flexible power-to-gas plants, energy storage etc., in supporting system balancing and network congestion management will depend strongly on the locations of renewable generation, storage sites, gas / hydrogen and electricity networks (Jentsch et al. 2014; Heymann and Bessa 2015; Ameli et al. 2020). ". This is also provided in section 6.4.5:"Hydrogen could also provide long-term storage in order to deal with extreme events, such as low output of renewable generation for long durations or a significant increase in demand driven by extreme weather conditions. "	Jonathan Cobb	World Nuclear Association	United Kingdom (of Great Britain and Northern Ireland)
84485	52	21	53	2	The system benefits of flexibility technologies represents an important element within the chapter. Other references that may be considered for supporting the synthesis across the literature include the empirical review of power-to-heat demand response (https://doi.org/10.1016/j.rser.2020.110489) and the review of flexibility potentials (https://doi.org/10.1016/j.apenergy.2017.12.073).	Rejected. The topic is interesting and important. However, space limits prevent us from addressing it here. In previous part the role of nuclear in providing flexibility is investigated in detail.	Siir KILKIS	The Scientific and Technological Research Council of Turkey	Turkey
73965	52	30	52	38	Flexibility also reduces the need for high-carbon firm capacity (not only the low carbon one)	Taken into account. Thanks for this. Since we are looking for decarbonsing the future, we mentioned low-carbon generation	Heleno Miguel	Lawrence Berkeley National Laboratory	United States of America
78513	52	30	52	38	Electricity should be reliable all hours of the year (even at nights and with no wind), only possible with two carbon-free sources: hydro and nuclear (which are also cheapest currently used sources)	Taken into account. Inflexible nuclear is removed and the role for nuclear is updated and clarified in flexbile/dispachable generation section:"In terms of nuclear generation, there is already some important development in making nuclear plants more flexible (e.g., in France (Office of Nuclear Energy, 2021)). Furthermore, development of small modular reactors could also support system balancing (FTI Cons. LLP., 2018). " Due to sapce limit we are not able to expand further.	Tomaž Žagar	Faculty for Energy Technology, University of Maribor	Slovenia

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
83929	52	31	52	32	Curtailment occurs due to 2 reasons: (1) low flexibility, and (2) mis-match between VRE output and load profile. There is no way of avoiding curtailment without a penality if curtailment is not party of the flexibility. The physics of the system shows that achieving an optimal system design is impossible without curtailment[1-7]. An optimal curtailment was proven to be an essential element of high VRE grid that carries several techno-economic benefits. Paper [2] and [8] gives simple review and [3] gives technoeconomic aspect. 1.Solomon AA, Kammen DM, Callaway D (2014) The role of large-scale energy storage design and dispatch in the power grid: a study of very high grid penetration of variable renewable resources. Applied Energy 134: 75–89. 2.Solomon A.A. Large scale photovoltaics and the future energy system requirement. AIMS Energy, 2019, 7(5):600–618 3.Solomon AA, Bogdanov D, Breyer C (2019) Curtailment-storage-penetration nexus in energy transition. Applied Energy 235:1351–1368 4.Solomon AA, Kammen DM, Callaway D (2016) Investigating the impact of wind-solar complementarities on energy storage requirement and the corresponding supply reliability criteria. Applied Energy 168: 130–145. 5. Solomon AA, Child M, Caldera U, et al. (2017) How large energy storage is needed to incorporate very large intermittent renewables? Energy Procedia 135:283–293 6.Solomon AA, Faiman D, Meron G (2011) Appropriate storage for high-penetration grid-connected photovoltaic plants. Energy Policy 40:335–344. 7. Solomon AA, Faiman D, Meron G (2010) Properties and uses of storage for enhancing the grid penetration of very large-scale photovoltaic systems. Energy Policy 38:5208–5222 8.Solomon AA, Child M, Caldera U, et al. Exploiting wind-solar resource complementarity to reduce energy storage need. AIMS Energy 8 (2020): 749–770.	Rejected. Thanks for this. Due to space limit the sentece is upodated slightly and a refrence is added.	Solomon Asfaw	LUT University	Finland
2851	52	33	52	35	Which analysis does this statement refer to? In which timeframe will be this capacity not required? Please cite the source.	Taken into account. The proper reference is added:"For example, analysis has demonstrated that flexibility technologies and advanced control systems could enable the UK's low-carbon emission targets by building 14 GW less nuclear or 20 GW less offshore wind generation (Strbac et al. 2015a). "	Leonardo Barreto	Head of center "EU&International"	Austria
8925	52	33	52	35	This statement appears highly questionnable. In other studies, when requiering to nuclear power, the flexibility of the system increases. I suspect that the hypothesis in the referred study are very rigid with respect to the flexibility of nuclear. Take care to that, because some authors are not aware of this fact. See for example: Cany et al. (2018) « Nuclear power supply: Going against the misconceptions. Evidence of nuclear flexibility from the French experience » C. Cany, C.Mansilla, G.Mathonnière, P.da Costa, Energy, Volume 151, 15 May 2018, pp 289-296 or SFEN (2019) « Le nucléaire français dans le système énergétique européen », JG Devezeaux de Lavergne, M. Berthélémy, V. Faudon, Didier Beutier Société Française d'Energie Nucléaire, 2019 http://www.sfen.org/sites/default/files/public/atoms/files/le_nucleaire_francais_dans_le_systeme_energetique_europeen_-_sfen_-_ppe.pdf	Taken into account. inflexible nuclear is removed and the role for nuclear is updated and clarified in flexbile/dispachable generation section:"In terms of nuclear generation, there is already some important development in making nuclear plants more flexible (e.g., in France (Office of Nuclear Energy, 2021)). Furthermore, development of small modular reactors could also support system balancing (FTI Cons. LLP., 2018). " Due to sapce limit we are not able to expand further.	Jean-Guy DEVEZEAUX DE LAVERGNE	Université Paris-Dauphine & Société Française d'Energie Nucléaire	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
55741	52	33	52	35	Suggest adding a U.S. example to this paragraph: "In the United States, analysis has also demonstrated the value of flexibility technologies. Flexibility in buildings and delivered through voluntary programs alone could reduce U.S. carbon dioxide emissions by 80 million tons annually and save $18B in power system costs per year by 2030 (US DOE, forthcoming)."	Added.	Government of United States of America	U.S. Department of State	United States of America
9813	52	36	52	36	state the full form of DAC in the first mention	Fixed	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
51369	52	36			Similarly, direct air capture (DAC) be used to sequester	Fixed	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
78629	52	36	52	38	it is highly unlikely that excess electricity is suitable for DAC operation, simply due to cost reasons. DAC operation is found regualrly to be operated in very high utilisation for cost reasons. This is detailed much in Breyer et al. (https://link.springer.com/article/10.1007/s11027-019-9847-y)	Taken into account. Regarding DAC, in transport section (6.4.5) details are provided, in which it is not probably a short-term solution:"Hence, to reduce emissions to zero, CO2 should be captured from biomass or from direct air capture (DAC) technologies (IRENA 2019b), although the short-term possibilities of net-negative emissions from DAC are questionable (Sekera & Lichtenberger 2020)" Due to space limit we are not able to expand further. In this section, the following is provided:"Similarly, heat required by direct air carbon capture and storage (DACCS) could be effectively supplied by inherent heat energy in nuclear plants, which would enhance the overall system efficiency (Realmonte et al. 2019)."	Christian Breyer	LUT University	Finland
2673	52	39	52	42	How is this bullet point different from the preceding one? I'd suggest to combine both.	Rejected. Thanks for this, however the current structure seems approproate.	Jan Wohland	ETH Zurich	Switzerland
73967	52	39	52	42	More than reducing the system peaks, flexibility reduces the uncertainty of those peaks, which decreases the need for reserve	Taken into account. the sentence is updated.	Heleno Miguel	Lawrence Berkeley National Laboratory	United States of America
37707	52	43	52	44	This kind of articulations create false narratives. Very high investment in the grid is needed to integrate renewables. Flexibility technologies will provide minor savings to the high inverstment. Overall, there will be a need to invest significantly in the strengthening of the grid.	Taken into account. This is presented in the following : "Analysis highlights that flexibility technologies and advanced control of integrated energy systems (e.g. considering the interaction between electricity, heating/cooling, gas/hydrogen, transport sectors), could reduce energy infrastructure investments by more than 20% in future low-carbon energy systems (Strbac et al. 2015a; Jacobson et al. 2019; Carbon Trust 2021)."	Ravi B Grover	Homi Bhabha National Institute	India
7869	52	46	52	46	would suggest adding cooling to the phrase -- of transport and heat sectors -- i.e. -- of transport, heating and cooling sectors	Added.	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
17379	53	3	53	3	Chapter 6.4.4 does not contain any estimate on the size of energy storage. Does the World powered with 100% renewables need 1000 TWh of storage (with maximum power 1000 GW)? 100 TWh, 10000 TWh? Not even an order of magnitude is given.These numbers must be provided as they present a starting point for estimations of the reuired resources (materials, land, energy investment, EROI...). Further comments on 6.4.4 cannot be given without this data.	Taken into account. The following is added:"In this context, if the integration of renewables is doubled by 2030, the total capacity of electricity storage could increase for around 200% (level to 2017 (4.67 TWh)) (Ralon, P et al., 2017)."	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
48131	53	3	53	3	It would be useful to see a discussion of seasonal underground thermal energy storage (boreholes, water pits, aquifers).	Rejected. No space to add more discussion, but see lines 42-44 "TES technologies can store both heat and cold energy for long periods, for example in 42 underground water reservoirs for balancing between seasons (Tian et al. 2019; Dahash et al. 2019), 43 storing heat and cold to balance daily and seasonal temperatures"	Mark Jacobson	Stanford University	United States of America
51233	53	3	63	20	6.4.4 Energy Storage for Low-Carbon Grids. A crucial information is lacking in this chapter: the order of magnitude of the fraction of the energy demand that will need to be covered by enerrgy storage depending on the share of intermittent/variable energy production. Without this information, it is impossible to put energy storage solutions in perspective as to the impact of these solutions in terms of costs, pressure on material resources and land use, EROI ...	duplicate of 17379	Eric PROUST	European Nuclear Society (ENS)	France
64321	53	3	58	42	This whole chapter on energy storage focuses on electricity. There should be some narrative on the role of thermal storage in conjunction with building heating and the beneficial effect of helping eliminate demand peaks on the electricity system as heat becomes electrified.	Rejected. No space to add more discussion, but see p56, line 43 " storing heat and cold to balance daily and seasonal temperatures in buildings..."	Peter North	Imperial College (part-time PhD student) /Calorem Ltd	United Kingdom (of Great Britain and Northern Ireland)
82647	53	3	53	12	Energy storage could reduce need for certain kinds of renewables as well as nuclear and fossil fuels with CCUS. In fact modelling by Sepulveda et al - The Role of Firm Low-Carbon Electricity Resources in Deep Decarbonization of Power Generation (https://www.sciencedirect.com/science/article/pii/S2542435118303866) show that firm low-carbon resources consistently lower decarbonized electricity system costs and that batteries and demand flexibility do not substitute for firm low-carbon resources. In many cases it is clear that electricity storage would make firm low carbon resources more competitive as it will raise night time market prices and allow storage providers to sell electricity at day time peaks. One of the earliest known examples of storage - pumped hydro – has been used for this purpose in UK	Taken into account. please see p54, line 8 network upgrades can thus be reduced (upgrade deferral), meaning that less low carbon generation will need to be built	Jonathan Cobb	World Nuclear Association	United Kingdom (of Great Britain and Northern Ireland)
43587	53	6	53	6	Remove "." after "transmission"	accepted, done	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy
73969	53	6	53	6	delete the period (punctuation mark) after "transmission".	duplicate of 43587; done	Heleno Miguel	Lawrence Berkeley National Laboratory	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
71613	53	8	53	12	Extension of the infrastructure is a cost efficient measure compared to many storage technologies, in future with lower storage costs and difficulties to extend infrastructures also storage can play a important role to build and optimize an efficient energy system	see p54, lines 8 "network upgrades can thus be reduced (upgrade deferral)" and 13 "support cost-effective energy system decarbonisation"	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
73971	53	8	53	8	replace fluctuating by "variable and uncertain"	accepted; done	Heleno Miguel	Lawrence Berkeley National Laboratory	United States of America
21011	53	13	53	13	Higer values are claimed for PHS systems (60-70% is given) Ref : Storing Energy: with Special Reference to Renewable Energy Sources; edited by Trevor M. Letcher, Elsevier, 2016, ISBN: 9780128034408. ttp://dx.doi.org/10.1016/B978-0-12-803440-8.00002-6. p25: « Over 80% for state of the art systems"	accepted; done; add ref Yang, C.-J., 2016: Chapter 2 - Pumped Hydroelectric Storage. In "Storing Energy: with Special Reference to Renewable Energy Sources", Letcher, T. M. Ed, Elsevier, 25–38 pp	Government of France	Ministère de la Transition écologique et solidaire	France
21013	53	13	53	13	On the last line of the table: Is this realy a "Roundtrip efficiency" , ie Power to Gaz to Power ? If so the values ("35%-60%") appear very high with available technology	Taken into account. Thanks for this. The values are checked again. Due to recent developments in hydrogen production technologies as well as projections for the future (e.g., SOECs; see section 6.4.5), the efficiency can be higher.	Government of France	Ministère de la Transition écologique et solidaire	France
29905	53	13	53	27	Please consider adding water storage (without pump) as an additional category as this is the major low carbon energy storage in N-Europe (Norway have >50 % of the storage potential in Europe.). Key reference; https://hydrocen.wpcomstaging.com/wp-content/uploads/2019/10/IEA_Hydropower_Flexible-hydropower-providing-value-to-renewable-energy-integration_White-Paper_Final.pdf	rejected - Definition of PSH to be limited to pumped hydroelectric storage, or closed loop only; this avoids controversy and confusion with hydropower.	Government of Norway	Norwegian Environment Agency	Norway
43589	53	13	53	26	Please shorten this caption, move references to footnotes and part of the explanation to the main text. Consider redesigning the table, in its current form it is quite unreadable. As a bare minimum, replace acronyms with their meaning, and switch to horizontal layout.	Taken into account. this is necessitated by the referencing style and limited space, but the caption has been shortened by moving references to a footnote	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy
51125	53	13	53	26	In Table 6.4, the definition of "roundtrip efficiency" should be given for the various technologies. For Power to Fuel, if it means efficency of the "power to fuel to power" process (it should, otherwise, it is misleading), the given figures -35 to 65%- appear suprisingly high. References for the given figures should be given, and checked.	Noted. references for all figures are in the caption; they may by now be out of date, but they were all checked	Eric PROUST	European Nuclear Society (ENS)	France
51371	53	13	53	26	Add note that for large-scale PSH, and to a lesser extent for CAES, locations are limited-	accepted; done	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
51373	53	13	53	26	unlike all the other storage technologies listed.	seems to be an extension of comment 51373	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
80473	53	13	53	26	The table is great and to be able to make comparisons between the technologies it would be even better to include the US$/kWh and the cost reductions over the past 10 years (if numbers for a storage technology exists). Both are essential metrics needed for comparisons. (optional: also include estimates for kWh/kg and kWh/m³)	rejected - Limited space for this table; Cost figures are highly variable, difficult to truly compare, either by granularity - some are for cells, some for whole packs, whole systems - or by financial value - some figures need to be converted to modern values, some do not state the year of reference	Moritz Riede	University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
73973	53	21	53	21	closing bracket missing ")"	accepted; done	Heleno Miguel	Lawrence Berkeley National Laboratory	United States of America
55743	53	26	53	26	This table misses the most important long duration energy storage technology -- specifically hydrogen PEM fuel cells, which are reasonably mature, have a significant opportunity to reduce cost, and have a roundtrip efficiency near the 40% range. Further, the discussion needs to recognize that for long duration energy storage, since annual capacity factors for LDES are typically in the neighborhood of 5%, the relatively short lifetime of PEM is not a constraint and instead the most important factor is getting the capital cost down as low as possible.	rejected - We specifically included reversible fuel cells, as a fuel cell by itself is not reversible. This is then comparable to the other roundtrip technologies. The type of fuel cell is not limited to PEM, only to its reversibility.	Government of United States of America	U.S. Department of State	United States of America
69571	53	26	53	27	The round-trip efficiency range of PSH is 65 to 85%. The cycle efficiency of Dinorwig, for example, is 74%, above the range indicated here.	duplicate of 21011; done	Cédric PHILIBERT	Institut Français des Relations Internationales	France
77369	53	26	53	27	The table lacks "reservori hydropower", and "hydropower", which provides many of the listed services in many countries.	rejected - limited space - if we add a column for specialised forms of one technology, we would have to do it for all of them	Atle Harby	SINTEF Energy Research	Norway
77371	53	26	53	27	As above 90 % of all grid-connected energy storage today is pumped hydro, and as there are very few installations of CAES and LAES, I don't find evidence that it is correct to categorize CAES and LAES at High and Medium levels of maturity, respectively.	rejected - CAES has been in operation since the 1960's; it is mature by those standards; LAES is only slightly behind CAES	Atle Harby	SINTEF Energy Research	Norway
77373	53	26	53	27	Roundtrip efficiency of PSH is 60-80%	duplicate of 21011; done	Atle Harby	SINTEF Energy Research	Norway
84347	53	26	53	27	Table 6.4: indicate storage dedicated to adequacy and those possibly dedicable to stability (TES, Scap)	Taken into account. Stability is added to the table, and in the text:"A greater proportion of renewable sources reduces system inertia, requiring more urgent responses to changes in system frequency, which rapid response storage technologies are able to provide (stability requires responses within subsecond timescale for provision of frequency and voltage control services). " The technologies which provde durational storage are dedicated to adequacy	Vincent MAZAURIC	Schneider Electric	France
2853	54	9	54	10	A sound load management in extreme weather situations and approaches to quickly isolate failures („islanding“), are fundamental to ensure the power system's capability to withstand disturbances with minimum acceptable service disruption. Besides storage, they require smart and flexible grids	rejected - Limited space	Leonardo Barreto	Head of center "EU&International"	Austria
51375	54	11			No single energy storage technology (EST) can provide all	accepted, but acronym to be expanded p53 line 4; done	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
77375	54	11	54	11	The statement is false, there are countries that only have hydropower to provide all EST services (Norway, Tadjikistan and others), There are simply no other technologies.	rejected - the statement is correct, in terms of globally-needed servicee	Atle Harby	SINTEF Energy Research	Norway
80475	54	11	54	11	“No single EST can provide all of required grid services” is not correct, at least when looking at table 6.4. There RHFC appear to tick all boxes.	accepted; in substance, yes, but not in volume and not cost-effectively; RHFC is a very immature technology - done	Moritz Riede	University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
71615	54	15	54	15	reference to Section 6.4.3.2 gives no source for needed storage volumens but describes storage technologies	Taken into account. The following is added:"In this context, if the integration of renewables is doubled by 2030, the total capacity of electricity storage could increase for around 200% (level to 2017 (4.67 TWh)) (Ralon, P et al., 2017)."	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
61999	54	16	54	18	There is positive statement about price development "This means that although costs today may be relatively high, there are significant opportunities for future cost reductions, both through technology innovation and through manufacturing scale." which needs to be balanced with market view. i.e. "Adding significant amounts of storage will reduce the price variation and therefore the profitability of additional and also existing storage, which will increase investment risk. Therefore system analysis and scenario tools need to be utilized to achieve the lowest cost system with additional financing instruments to reduce risk."	accepted; done	Esa Vakkilainen	LUT University, Lappeenranta	Finland
10947	54	19	54	19	change "incudes" to "includes"	accepted; done	Dong-Woon NOH	Korea Energy Economics Institute	Republic of Korea
16371	54	19	54	19	change "incudes" to "includes"	duplicate of 16371; done	Government of Republic of Korea	Korea Meteorological Administration (KMA)	Republic of Korea
71617	54	25	54	26	Storage provides a pillar in setting up a cost efficient infrastructure for carbon free transport via electric mobility. Storage and local distribution grid infrastructure will need investment. The future challenge will be to find the most efficient solution and set-up for a electric cars.	rejected - This is to be discussed in the section on transport; limited space in this section to adequately cover applications of ESTs	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
77383	54	29	58	32	The whole chapter on energy storage technologies should be better written to explain for all technologies: installed capacity (MW) today, available storage volume (TWh) today, normal and possible ramp rates, what services at what timescale they can provide, etc. Thsi may be given in a table and also added for all technolgies. Their environmental impact should also be mentioned for all, not only for some. As the chapter is written now, it is of poor quality and does not offer the reader important insight.	rejected - Limited time to search the literature to find this level of information for every technology; Limited space - some of this was in the first draft, but removed; reviewer needs to consider the space limitations and the complexity of the topic	Atle Harby	SINTEF Energy Research	Norway
84349	54	29	58	42	Indicate and discuss storage dedicated to adequacy (slow due to matter diffusion dependant) and those possibly dedicable to stability (inrushable or on-grid) for all the subsections within 6.4.4.1.	Taken into account. Stability is added to the table, and in the text:"A greater proportion of renewable sources reduces system inertia, requiring more urgent responses to changes in system frequency, which rapid response storage technologies are able to provide (stability requires responses within subsecond timescale for provision of frequency and voltage control services). " The technologies which provde durational storage are dedicated to adequacy	Vincent MAZAURIC	Schneider Electric	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
29907	54	30	54	48	Please consider mentioning the need for ecosystem based management principles to be used to avoid severe environmental and social negative impacts from hydropeaking in this sub-chapter, with refs to key reviews (e.g. Hayes et al, 2019 - https://www.mdpi.com/2071-1050/11/6/1547).	Rejected. Too specific, but reference added add ref Hayes et al., 2019 - https://www.mdpi.com/2071-1050/11/6/1547	Government of Norway	Norwegian Environment Agency	Norway
29909	54	30	54	48	Please consider adding more description on different HP water storage schemes and mitigation, managment needed should be added, as there is an obvious unbalance regarding technologies and LCA for different technologies!	rejected - Definition of PSH to be limited to pumped hydroelectric storage, or closed loop only; this avoids controversy and confusion with hydropower.	Government of Norway	Norwegian Environment Agency	Norway
77377	54	30	54	39	Add a sentence somewher to explain how storage hydropower is working as energy storage: Storage hydropower keep storing the inflow in the reservoir at off-peak times (during day, week, season or year), and generates whein it is needed.	rejected - Definition of PSH to be limited to pumped hydroelectric storage, or closed loop only; this avoids controversy and confusion with hydropower.	Atle Harby	SINTEF Energy Research	Norway
78481	54	30	55	2	This paragraph on pumped hydro lacks expertise to an extent that it is obvious to me as a non-expert in pumped hydro. I suggest adding some sentences about off-river pumped hydro between line 39 and 40 along the following lines: "Off-river pumped hydro energy storage is possible on sites where there is a lower and an upper reservoir in close distance. Either or both may need a dam and are filled with rainwater (no river required). About 616'000 potential sites exist that fulfil stringent technical/geological criteria (such as dam height, water volume etc.) and where fragile environmental areas and urban regions are not considered [Ref: A. Blakers et al., DOI: 10.1109/JPHOTOV.2019.2938882; see also http://re100.eng.anu.edu.au/global/index.php for data and an online map]. These potential sites have a storage potential of about 23 million GWh, which is about 100 times more than needed to support a 100% global renewable energy system [Fasihi and Breyer 2020, already cited], and therefore allows for careful choice considering all aspects of environmental impacts. Evaporation is smaller than rainfall in most regions and is a small fraction of agricultural water use. Costs, including 30 years of depreciation, varies by region and is near US$10/MWh in most cases." If there is not enough space to add this text, an option is to remove the two sentences in lines 43 – 46 where a technology is described that is not mature.	rejected - Definition of PSH to be limited to pumped hydroelectric storage, or closed loop only; this avoids controversy and confusion with hydropower.	Pietro Altermatt	Trinasolar, Changzhou, China	Germany
4121	54	32	54	34	"Hydropower plants incorporating an element of storage, either through seasonal reservoirs ..." If a hydropower plant has a (seasonal) reservoir but does not perform pumping up water to upper reservoir, then it is not PSH, but just a conventional hydropower. To avoid confusion, such a conventional type should be excluded from the discussion here, if this section is entitled "PSH". Otherwise readers are not sure if the following line "... account for 97% of worldwide electricity storage capacity" meant to include conventional hydropower with reservoir, or not.	accepted; done	Tatsuki Ueda	National Agriculture and Food Research Organization	Japan
4181	54	32	54	32	Include a statement on the conservation of energy: "One advantage of this type of gravity-fed system is that it reduces the non-conservative energy losses (such as frictional heat losses) that are typically associated with systems incorporating the conservation of mechanical enegy from gravitational potential to kinetic energy transformations.	Rejected. Too technical for this level of writing	Neil M. Mulchan	Adventure Physics, LLC	United States of America
55745	54	32	54	34	This sentence includes a statistic of 97% for pumped hydro storage, but a similar sentence on page 6-20, lines 35-36, states that the amount is 96%. This difference should be reconciled or additional context should be included to clarify the difference in values.	The value is correct! Checked again also with another reference as well (Ralon, P et al., 2017).	Government of United States of America	U.S. Department of State	United States of America
9185	54	34	54	34	"account for 97% of worldwide electricity storage capacity (IEA 2018c)": please mention the total storage capacity (TWh) it would be very interesting for the readers.	duplicate of 17379	Marin Constantin	RATEN ICN	Romania

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
21015	54	34	54	34	It would be useful to state explicitly the current capacity (in TWh)	duplicate of 17379	Government of France	Ministère de la Transition écologique et solidaire	France
51127	54	34	54	34	"account for 97% of worldwide electricity storage capacity (IEA 2018c)": it would be useful to provide the figure of the absolute capacity (TWh)	duplicate of 17379	Eric PROUST	European Nuclear Society (ENS)	France
77385	54	34	54	37	There are many new and innovative pumped storage plants that can give very rapid response.	duplicate of 77351	Atle Harby	SINTEF Energy Research	Norway
69575	54	35	54	37	This statement is excessive. For example, the Dinowig PSH in the UK is able to achieve an output of 1728 MW from zero withing 16 seconds.	Taken into account. Thanks for this. The sentece is updated:"PHS is best suited to balancing energy needs at a large scale and advances in the technology now allow both rapid response and power regulation in both generating and pumping mode (Valavi and Nysveen, 2018; Kougias et al., 2019; Dong et al., 2019). "	Cédric PHILIBERT	Institut Français des Relations Internationales	France
77351	54	35	54	37	The sentence "but conventional PSH plants are not able to provide services requiring a very rapid response and provide power regulation only during generation, not during pumping." is incorrec. Ternary units and units with hydraulic short cercuits can ramp up and down to very rapid response. Modern technology with variable speed pump-turbine can provide power regulation both in generating and pumping mode. This sentence must be deleted or re-written to: "Modern technology in PSH now allows rapid response and power regulation in both generating and pumping mode". There are many examples of PSH that provides synchronous inertia, voltage control, etc. See also https://xflexhydro.net/ancillary-services-matrix. -Variable speed review: https://ieeexplore.ieee.org/document/8387741 -Variable speed with FSFC (frequency converter): https://iopscience.iop.org/article/10.1088/1742-6596/813/1/012007/pdf And https://www.researchgate.net/publication/315968804_Simulation_of_pump-turbine_prototype_fast_mode_transition_for_grid_stability_support -Variable speed with DFIM (doubly fed induction machine): https://www.sciencedirect.com/science/article/abs/pii/S0960148120308685 -Hydraulic short circuit: https://ieeexplore.ieee.org/abstract/document/7439818 -Hydraulic short circuit and ternary units: https://iopscience.iop.org/article/10.1088/1742-6596/813/1/012013 -Review of some general innovative concepts in hydro (incl PSH): https://www.sciencedirect.com/science/article/pii/S1364032119304575#sec7 Also a higher level publication is IRENA's innovation brief on PSH (table at end includes various projects, discussed): https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Jul/IRENA_Innovative_PHS_operation_2020.pdf?la=en&hash=4533ABDD9EA1D0755720FF46F3241FAB56C65014	accepted - sentence change made and some references added	Atle Harby	SINTEF Energy Research	Norway
69577	54	37	54	39	There is some confusion here between PSH and standard HP. PSH are much smaller reservoir than barrage HP, as they do not need to accumulate precipitations over weeks and months. They are often built close to existing standard HP. Disruptions to local community and environment are minimum. The reference to section 6.4.2.3 reveals that confusion. At least the statement should be seriously nuanced.	accepted - Definition of PSH to be limited to pumped hydroelectric storage, or closed loop only; this avoids controversy and confusion with hydropower.	Cédric PHILIBERT	Institut Français des Relations Internationales	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
69573	54	38	54	39	This is an incorrect interpretation of the reference. The IEA 2018c (World Energy Outlook) states that PSH "currently accounts for 97% of global storage capacity". That is 158 GW at end 2019 (Hydropower Status Report 2020, International Hydropower Association). This 97% figure by the IEA does not take in account all hydropower plants incorporating an element of storage with seasonal reservoirs, which are many. Morover, PSH is continuously expanding, at a similar pace, in absolute capacity terms, than on-grid batteries. Furthermore, a comparison in storage volumes, i.e. TWh, would reveal a greater difference still, as PSHY usually have a volume of 15 to 50 full load hours, while batteries have 1 to 4 full load hours: see, e.g. https://www.iea.org/articles/will-pumped-storage-hydropower-expand-more-quickly-than-stationary-battery-storage. This section should be expanded somewhat given the current and likely future preeminence of PSH among storage technologies.	accepted - Definition of PSH to be limited to pumped hydroelectric storage, or closed loop only; this avoids controversy and confusion with hydropower.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
69579	54	40	54	42	Advanced PSH plants are being deployed already, of two main types, both allowing for frequency control in both pumping and turbining modes. One type, AS-PSH (adjustable speed) uses variable speed pumps. The other type, that of "ternary units" or "T-PSH", puts turbines and pumps on the same shaft, allowing for an extremely rapid shift from pumping to turbining mode and vice-versa. These are not exactly new: the Ffestiniog PSH with 4 tertiary units was commissioned in the UK in 1963. See, e.g. Dong et alii, 2019, Modelling and simulation of ternary pumped storage hydropower for power system steudies, IET Gener. Transm. Distrib.13 Iss 19: 4382-4391. Both AS-PSH and T-PSH plants have since been built in many countries.	duplicate of 77351; done	Cédric PHILIBERT	Institut Français des Relations Internationales	France
4123	54	46	54	48	"Storage of energy as gravitational potential can also be implemented using materials other than water, such as rocks and sand." Are there any examples of such a technology in commercial operation? Even if there is one, can it be called "hydropower" as the section title dictates?	rejected - yes, there are some examples;changing the title would be confusing.	Tatsuki Ueda	National Agriculture and Food Research Organization	Japan
21017	54	46	54	48	The potential and efficiency is very small and it should be said explicitely	Not clear what the comment is refrring to - is it just about the non-water forms, or about PHS in general? If the latter, see extensive comments by PHS experts	Government of France	Ministère de la Transition écologique et solidaire	France
4183	54	48	54	48	Include a statement on material viscosity: "However, using non-fluid, high-viscosity materials lowers the efficiency of the system due to higher frictional losses."	Rejected. Too technical for this level of writing	Neil M. Mulchan	Adventure Physics, LLC	United States of America
1571	55	1	55	2	"but with limited potential relative to the potential storage needs in future low-carbon electricity grids.": This statement neglects the recent work with off-river pumped hydro. Blakers et al. state: "A global survey of off-river (closed-loop) pumped hydro energy storage sites identified 616 000 promising sites around the world with a combined storage capacity of 23 millionGWh, which is two orders of magnitude more than required to support 100% global renewable electricity." (IEEE JOURNAL OF PHOTOVOLTAICS, VOL. 9, NO. 6, NOVEMBER 2019, p.1828).	rejected - Definition of PSH to be limited to pumped hydroelectric storage, or closed loop only; this avoids controversy and confusion with hydropower.	Martin Green	UNSW Sydney	Australia

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
69581	55	1	55	2	The "limited potential" of PSH is an unsubstantiated claim. It too belongs to the common confusion between standard HP and PSH. Various studies have, to the opposite, revealed extensive potential. For example, Gimeno-Gutiérrez, Lacal-Arantegui, 2013, An assessment of the European potential, the Joint Research Center of the European Commission, showed a EU potential of 33 TWh storage, 10 times à mucch as the existing storage volume. The global pumped hydro atlas (http://re100.eng.anu.edu.au/global/) shows the 616 000 potential sites around the world that have been identified by the Australian National University (2019), with a total volume of 23 000 TWh. Of course only a fraction can be developed, some large opportunities in some regions would vastly exceed the demand, etc. Still, if you compare with total existing volume capacity of all existing PSH, about 9 TWh, you see that if you only develop 1/1000 of this potential you more than double the existing basis, and if you develop 1% you multiply it by over 20. Furthermore, the ANU study probably does not take in account seawater PSH options (e.g. the Okinawa plant, now decommissioned, or the Valhalha project in Chile), nor the "twin lakes" option for African lakes developed by Lempérière (Nombré et alii, 2019, Prospects for African hydropower in 2050, Hydropower & Dams, Issue Two). In any case, PSH does not show a "limited potential" in comparison to our needs, and even less so in comparison to other storage technologies. The International Hydropower Association estimates that the global PSH capacity will grow by 78 GW by 2030, considerably more than other forms of energy storage technologies. (2020 Hydropower Status Report).	accepted - Definition of PSH to be limited to pumped hydroelectric storage, or closed loop only; this avoids controversy and confusion with hydropower.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
77379	55	1	55	2	The statement is false and not documented. Pumped storage does not have limited potential. Please see International Hydropower Association (IHA) "Pumped storage tracking tool" at https://www.hydropower.org/hydropower-pumped-storage-tool. IHA documents there are more than 100 pumped storage projects currently in the pipeline, existing pumped hydropower storage capacity is expected to increase by almost 50 per cent by 2030 – from 161,000 MW today to 239,000 MW.I would not call an increase of 78 000 MW as "limited". The statement must be changed.	Taken into account. Thanks for this. The sentence is updated:"Storage of energy as gravitational potential can also be implemented using materials other than water, such as rocks and sand. Pumped technology is a mature technology (Barbour et al. 2016; Rehman et al. 2015) and an important contributor of electricity storage (IHA 2021), in supporting the transition to future low-carbon electricity grids."	Atle Harby	SINTEF Energy Research	Norway
1573	55	3	57	19	It is weird and also confusing that redox batteries do not make the "Battery" classification and have their own disjointed section, seeing they are behind only Li-ion in grid deployment. Their inclusion in the "battery" section would be sensible, even as a sub-heading; also inclusion of their characteristics in Table 6.5.	Redox batteries is now included in the table	Martin Green	UNSW Sydney	Australia
21019	55	3	55	3	We suggest to state the current battery capacity (in TWh)	duplicate of 17379	Government of France	Ministère de la Transition écologique et solidaire	France
55747	55	3	55	13	This paragraph states that LABs have been used for decades in grid applications, but that LIBs are replacing them. Given that LIBs are preferred, especially for EVs because of weight benefits, is the chemistry that much more preferable to other, heavier batteries? The weight benefit is not as relevant for grid applications since they are stationary. Has the focus on LIBs for mobile applications resulted in such significant cost reductions that they are now the preferred option for most applications?	Rejected. Thanks for this - The topic is interesting and important. However, due to space limit we are not able to expand further.	Government of United States of America	U.S. Department of State	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
85781	55	7	55	7	Suggest author review for consistent use of terms: “lithium-ion batteries" referred to here, whereas other sections use "Li-ion".	Fixed	Government of Australia	Department of Industry, Science, Energy and Resources	Australia
37709	55	10	55	11	Batteries cannot provide seasonal storage and this aspect needs to be highlighted upfront in the report. Public should not be fed on false narratives that once storage is in place, grid with significant intermittent sources will become reliable. In India, it rains continously for four months in several parts of the country. Sun is not visible for days together in cities like Mumbai during June to September. Battery storage cannot provide reliability to a load center like Mumbai. Answer lies in a having a broad portfoliao of low-carbon technologies including hydro, nuclear, solar and wind. To ensure credibility of the IPCC process, please provide a correct narrative to the public.	rejected - see p54, line 11 "No single EST can provide all of required grid services – a portfolio of complementary technologies 11 working together can provide the optimum solution"; Table 6.4 indicates that batteres cannot provide seasonal storage	Ravi B Grover	Homi Bhabha National Institute	India
77165	55	14	55	14	Consider adding Ca and Mg ion batteries in the table, see for example: Gummow, R. J., Vamvounis, G., Kannan, M. B., & He, Y. (2018). Calcium-Ion Batteries: Current State-of-the-Art and Future Perspectives. Advanced Materials, 30(39), 1801702. https://doi.org/https://doi.org/10.1002/adma.201801702	rejected - These technologies are very low TRL; limited space	Carles Pelejero	Institut de Ciències del Mar, CSIC	Spain
51377	55	19	55	20	Table 6.5 consider adding a line Liquid metal batteries under development. A recent review is by	rejected - These technologies are very low TRL; limited space	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
51379	55	19	55	20	Yu Ding, Xuelin Guo, and Guihua Yu, https://pubs.acs.org/doi/10.1021/acscentsci.0c00749	seems to be an extension of comment 51377	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
71619	55	21	55	22	Maybe it should be added that batteries could be a main enabler for low cost carbon free mobility and bring additional properties for system services	rejected - see p 55 line 28 "The superior characteristics of LIBs will keep them as the dominant choice for EV"	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
37711	55	22	55	27	Drawbacks of battery storage need to be highlighted upfront in the report.	rejected - drawbacks are discussed where appropriate	Ravi B Grover	Homi Bhabha National Institute	India
52277	55	22	55	26	No mention of environmental impacts on extracting such elements. Should be included in the discussion.	accepted - added "particularly of mineral extraction ", p55, line 26	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
78245	55	22	55	26	Omission - Drawbacks associated with battery storage need to be highlighted text.	rejected - drawbacks are discussed where appropriate	Reetesh Chaurasia	Department of Atomic Energy, Government of India	India
47107	55		55		Table 6.5: the citation for LIB State of art price USD $176/kWh in 2017 in this table is Bloomberg Energy Finance 2019, this citation cannot be found in the reference. A possible source for the missing reference for this data (https://about.bnef.com/blog/behind-scenes-take-lithium-ion-battery-prices/) suggest that battery pack price at $176/kWh in 2018, not 2017 as suggested in Table 6.5 of this report. Both the citation and the text needs correcting.	Fixed	Kenneth Laberteaux	Toyota Motor North America-R&D	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
62001	56	10	56	14	When discussing "compressed air storage" and "high efficiency" one should note that especially CAS has the problem that at one point of the cycle the efficiency is high, but as the storage pressure inccreases during adding air (energy storage) and decreases during air removal (energy withdrawal) it is extremely difficult to manufacture highly efficient machinery for that. So typically efficiency is high for the initial or high pressure operation and is dramatically reduced for lower pressure ratios. This is highlighted well in the reference on line 13 "(Wang et al. 2017c)". The method suggested by (Wang et al. 2017c) i.e. deep sea storage is not currently used but can maybe in the future be applied.	rejected - Too technical for this level of writing	Esa Vakkilainen	LUT University, Lappeenranta	Finland
69583	56	11	56	14	Conventional CAES still use natural gas. New low carbon CAES technologies have been developed, but not deployed. The same for small-scale CAES.	Taken into account. The following sentence is updated:"Although CAES technologies have been developed, there are no many installations at present (Blanc et al., 2020 ;Wang et al. 2017b). While the opportunities for CAES are significant, with an excellent global geological storage potential of about 6.5 PW (Aghahosseini and Breyer 2018), a significant amount of initial investment is required. "/ also we provided the following as well: "While 11 conventional CAES has used natural gas to power compression, new low carbon CAES technologies, 12 such as isothermal or adiabatic CAES, control thermal losses during compression and expansion (Wang 13 et al. 2017c)."	Cédric PHILIBERT	Institut Français des Relations Internationales	France
71621	56	15	56	15	Development and diffusion of CAES technologies are not very dynamic in recent years, so competitiveness compared to batteries is not given as indicated in the next paragraph ("not many installations to date").	Taken into account. Thanks for this. The following is updated:"AES technologies have been developed, but however not many installations to date (Blanc et al., 2020 ;Wang et al. 2017b). "	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
77381	56	17	56	24	Please give concrete numbers on how many power plants of CAES there are in the world. It is only 2, built in the 1970s. It must also be emphasized that the compressed air of the two first CAES projects is used to drive gas turbines when generating. CAES may have severe environmental impacts and this must be mentioned here - at the same level as it is mentioned for pumped hydro	accepted; changed p56, line 17 to "CAES is a mature technology in use since the 1970s, but there have only been two major installations to date"	Atle Harby	SINTEF Energy Research	Norway
51129	56	18	56	18	"There have not been many installations to date": too vague, precise how many installations and which total capacity	duplicate of 77381; done	Eric PROUST	European Nuclear Society (ENS)	France
9187	56	19	56	19	"storage potential of 6.5 PW": check other source, it is a power (PW) not an energy storage (PWh!)	accepted: added "h"	Marin Constantin	RATEN ICN	Romania
21077	56	19	56	19	The reference that is provided mentions 6.57 PWh (an energy potential) and not 6,5 PW (which is a power)	duplicate of 9187; done	Government of France	Ministère de la Transition écologique et solidaire	France
51131	56	19	56	19	"storage potential of 6.5 PW": there is obviously a typing mistake: one stores energy, not power, so that the unit of energy storage potential is PWh, not PW. Check the reference	duplicate of 9187; done	Eric PROUST	European Nuclear Society (ENS)	France
69585	56	23	24	24	"Far more siting options than PSH and poses few environmental impacts " is an unsubstantiated claim. There are 2 CAES plants in the world, vs. hundreds PSH	Rejected; not with the correct definition of PHS; the limited number of installations for CAES does not reflect their potential, but rather technology "fashions"	Cédric PHILIBERT	Institut Français des Relations Internationales	France
74199	56	35	57	8	This section should be modified to include a specific discussion of molten salt storage.	rejected - limited space	Jeffrey Merrifield	Pillsbury Law Firm	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
9585	56	36	57	8	it is better to refer to "latent heat storage", "sensible heat storage", and "storage based on chemical and sorption reactions, usually known as thermochemical" instead of "latent TES", "sensible TES", and "thermochemical TES".	accepted, changed "reversible chemical reactions" to "reversible chemical and sorption reactions"	Jaume Gasia	Jose Antonio Romero Polo SA	Spain
9587	56	36	57	8	it should be mentioned somewhere that TES also allows balancing the electrical grid (e.g. TES systems in solar power plants)	accepted - added sentence "TES systems integrated with solar power plants can also be used to balance the electrical grid."	Jaume Gasia	Jose Antonio Romero Polo SA	Spain
64323	56	36	47	8	TES also refers to thermal storage which is not addressed here and perhaps should be. See above comment.	TES as thermal energy storage is demonstrated in detail in this section:"Thermal Energy Storage (TES). Thermal energy storage refers to a range of technologies exploiting the ability of materials to absorb and store heat or cold, either within the same phase (sensible TES), through phase changes (latent TES), or through reversible chemical reactions (thermochemical TES). Pumped Thermal Energy Storage (PTES), a hybrid form of TES, is an air-driven electricity storage technology storing both heat and cold in gravel beds, using a reversible heat-pump system to maintain the temperature difference between the two beds and gas compression to generate and transfer heat (Regen 2017). TES technologies can store both heat and cold energy for long periods, for example in underground water reservoirs for balancing between seasons (Tian et al. 2019; Dahash et al. 2019), storing heat and cold to balance daily and seasonal temperatures in buildings and reducing heat buildup in applications generating excessive waste heat, such as data centers and underground operations. TES has the potential to be much cheaper than batteries and has the unique ability to capture and reuse waste heat and cold, enabling the efficiency of many industrial, buildings, and domestic processes to be greatly improved (high confidence). Integration of this capability into energy systems is particularly important, as the global demand for cooling is expected to grow (high confidence) (Peters and Sievert 2016; Elzinga et al. 2014). Sensible TES is well developed and widely used; latent TES is less developed with few applications.	Peter North	Imperial College (part-time PhD student) /Calorem Ltd	United Kingdom (of Great Britain and Northern Ireland)
71623	56	36	57	8	Thermal Energy storage should be higher prioritized than Compressed air storage (see and align with box 6.6), thermal energy storage in combination with heat pumps (at single homes or in heating networks) should be included in here. This storage technology is expected to provide a large contribution to low carbon energy systems. At the same time it provides substantial flexibility to the system.	Rejected. The order has nothing to do with priorities.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
5365	56	39	56	39	Why do you specify "an electrcity storage technology"? It's a thermal energy storage.	Rejected - PTES was used to balance electricity; it is also a thermal storage, which is why it is in this section, but it has been used for electricity	Michel SIMON	Retraité/ Pdt d'association	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
14817	56	46	57	4	It may be relevant to mention that large-scale integration of sensible TES in the form of aquifer TES has a particularly large technical potential (Fleuchaus et al., 2018; https://doi.org/10.1016/j.rser.2018.06.057), as up to half of the global urban population lives in areas theoretically suitable for aquifer TES (Bloemendal et al., 2015; http://dx.doi.org/10.1016/j.scitotenv.2015.07.084). However, achieving this potential will require careful management of potential environmental impacts on the subsurface as well as appropriate governance. This issue is already emerging in areas of active aquifer TES development such as the Netherlands; demand for aquifer TES is leading to a shortage of subsurface space under current planning methods in certain cities, and therefore to a revision of provincial planning guidelines - e.g. Bloemendal et al., 2018; https://doi.org/10.1016/j.apenergy.2018.02.068	accepted; added "sensible TES in aquifers is growing (Fleuchaus et al. 2018), but environmental impacts will need to be carefully managed (Bloemendal et al. 2018)."	Marc Jaxa-Rozen	University of Geneva	France
6047	56				Pinegar, Haruka, and York R. Smith. "Recycling of end-of-life lithium ion batteries, part I: commercial processes." Journal of Sustainable Metallurgy 5, no. 3 (2019): 402-416.	accepted; added reference	Adam Burak	University of Michigan	United States of America
21021	57	15	57	15	About "[...] as the primary energy source": Isn't that obvious ? Flywheel are for energy storage: they are not an energy source neither in vehicules not on the ground.	rejected - it is not obvious to the target audience	Government of France	Ministère de la Transition écologique et solidaire	France
28519	57	46	58	12	I do not see how production of gas and injection to the gas grid fit with energy storage. I have the same hard time to understand how methanation also fits in the context of an energy storage discussion. I rather see these solutions as energy conversion technologies (and rather inefficient ones). Ammonia - due to toxicity - is not fit for injection in the gas grid. The sentence on lines 47 and 1 is therefore requiring a correction.	accepted, changed "limited quantities of these fuels" to "limited quantities of some of these fuels"	Pierpaolo Cazzola	International Transport Forum	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
60459	57	46	58	5	The definition of power to fuels is outdated and incomplete and the statement on CH4 emissions is inadequate in this section as 100% of the methane produced by power to gas can be injected in existing distribution and use infrastructure and that does not bring more emissions than existing fossil methane distribution systems (Henni et al., 2021, Applied Energy, 288, 116597). The base of the problem is to stop putting fossil carbon to the atmosphere so in producing methane via power-to-gas, it is recycled methane that is injected through the infrastructure, so it will anyway decrease the amount of fossil carbon to the atmosphere. CO2-based fuels are produced via the so-called "power-to-fuel" approach enabling the production of hydrocarbon fuels (e-fuels) using CO2 and green H2, i.e. hydrogen generated by the electrolysis of water with renewable energy (e.g. Breyer et al., 2015, Sternberg and Bardow, 2015, Dimitrou et al., 2015, Fasihi et al., 2017, Shih et al. 2018, Anwar et al., 2020). Artz et al., 2019 have shown that the largest reduction in the absolute amount of greenhouse gas emissions could be achieved by coupling of highly concentrated CO2 sources from CO2-emitting sectors with carbon-free hydrogen or electrons from renewable power via this approach. . Biogenic CO, H2 (Syngas) or CO2 from biomass conversion can also complete those resources reducing again the carbon intensity of the CCU product while valorizing thoses molecules (Ostadi et al., 2019) When it comes to alternative fuels, CO2-based fuels should be considered as a drop-in solution. Even with all possible efforts to reach the 2030 emission targets, the current gas infrastructure worldwide will not allow for a fast and global deployment of an hydrogen economy in the transport, energy and industrial sectors (e.g. Muratori et al., 2018, Gumber and Gurumoorthy, 2018). In contrast, e-CH4 can be used with the current natural gas infrastructure, especially in the energy and high heat industrial sectors (Deutz et al., 2018, Ram et al., 2020). In the transport sector, e-CH4 might not be the best solution as leaks are likely to occur, but methanol could be used efficiently with the existing infrastructures, especially for aviation and shipping (Schemme et al, 2017). At short-term, the role of hydrogen would first be to form methanol or other	Taken into account. Thanks for this. The sentence is updated:"The process of using electricity to generate a gaseous fuel, such as hydrogen or ammonia, is termed power-to-gas (P2G) (Gül et al. 2020) and injected to the existing gas infrastructure (section 6.4.5), with the added benefit of decarbonizing gas (Brandon et al. 2015), and combined cycle gas turbines can be converted to run on hydrogen. For greater compatibility with existing gas systems and appliances, the hydrogen can be methanated using captured carbon (Thema et al. 2019) (i.e., synthetic fuels), however methane has high global warming potential and its supply chain emissions have been found to be significant (Balcombe et al. 2013)." For more explanation pls refer to section 6.4.5 (energy transport)	Célia Sapart	Université Libre de Bruxelles / CO2 Value Europe	Belgium
64287	57	46	58	5	For the methanisation of hydrogen to be an effective decarbonisation technology, methane emissions from transportation and distribution networks would have to be eliminated. Gas pipelines today are often associated with large sources of vented and/or fugitive emissions. In March 2021, a study published on the ESA webpage showed that several methane emission events could be detected around pipeline installations in Russia and other countries (https://www.esa.int/Applications/Observing_the_Earth/Copernicus/Sentinel-5P/Monitoring_methane_emissions_from_gas_pipelines).	accepted, added two references	Christian Lelong	Kayrros	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
76319	57	46	58	5	The definition of power to fuels is outdated and incomplete and the statement on CH4 emissions is inadequate in this section as 100% of the methane produced by power to gas can be injected in existing distribution and use infrastructure and that does not bring more emissions than existing fossil methane distribution systems (Henni et al., 2021, Applied Energy, 288, 116597). The base of the problem is to stop putting fossil carbon to the atmosphere so in producing methane via power-to-gas, it is recycled methane that is injected through the infrastructure, so it will anyway decrease the amount of fossil carbon to the atmosphere. CO2-based fuels are produced via the so-called "power-to-fuel" approach enabling the production of hydrocarbon fuels (e-fuels) using CO2 and green H2, i.e. hydrogen generated by the electrolysis of water with renewable energy (e.g. Breyer et al., 2015, Sternberg and Bardow, 2015, Dimitrou et al., 2015, Fasihi et al., 2017, Shih et al. 2018, Anwar et al., 2020). Artz et al., 2019 have shown that the largest reduction in the absolute amount of greenhouse gas emissions could be achieved by coupling of highly concentrated CO2 sources from CO2-emitting sectors with carbon-free hydrogen or electrons from renewable power via this approach. . Biogenic CO, H2 (Syngas) or CO2 from biomass conversion can also complete those resources reducing again the carbon intensity of the CCU product while valorizing thoses molecules (Ostadi et al., 2019) When it comes to alternative fuels, CO2-based fuels should be considered as a drop-in solution. Even with all possible efforts to reach the 2030 emission targets, the current gas infrastructure worldwide will not allow for a fast and global deployment of an hydrogen economy in the transport, energy and industrial sectors (e.g. Muratori et al., 2018, Gumber and Gurumoorthy, 2018). In contrast, e-CH4 can be used with the current natural gas infrastructure, especially in the energy and high heat industrial sectors (Deutz et al., 2018, Ram et al., 2020). In the transport sector, e-CH4 might not be the best solution as leaks are likely to occur, but methanol could be used efficiently with the existing infrastructures, especially for aviation and shipping (Schemme et al, 2017). At short-term, the role of hydrogen would first be to form methanol or other	duplicate of 60459	Deepak PANT	Flemish Institute for Technological Research (VITO)	Belgium
78631	57	46	58	12	the statements are right, that PtX offers excellent options for balancing; however, PtX is not much required for storage to produce again electricity. This has been shown on a global scale by Bogdanov et al. (https://www.nature.com/articles/s41467-019-08855-1) indicating that not more than 2% of seasonal storage is required in a well balanced power system (to be found with the keyword 'SNG' in the article), as analysed in hourly resolution and a broad technology portfolio. Such an information will be for sure important in this section.	Taken into account. Thanks for this. The sentence is updated:"PtX can provide all required grid services, depending on how it is integrated. Although, PtX is not much required for storage to produce again electricity (Bogdanov et al., 2019) due to the current low roundtrip efficiency of converting electricity to fuel and back again, however there is still a need for distributable fuels (hydrogen, methane, ammonia, synthetic hydrocarbons), for example in energy systems lacking the potential for renewables and/or many applications requiring the high energy density of chemical storage, such as transport of heavy goods and heating/cooling of buildings (Gül et al. 2020). Research into more efficient and flexible electrolyzers which last longer and cost less is needed (Brandon et al. 2015)."	Christian Breyer	LUT University	Finland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
83703	57	46	58	5	The definition of power to fuels is outdated and incomplete and the statement on CH4 emissions is inadequate in this section as 100% of the methane produced by power to gas can be injected in existing distribution and use infrastructure and that does not bring more emissions than existing fossil methane distribution systems (Henni et al., 2021, Applied Energy, 288, 116597). The base of the problem is to stop putting fossil carbon to the atmosphere so in producing methane via power-to-gas, it is recycled methane that is injected through the infrastructure, so it will anyway decrease the amount of fossil carbon to the atmosphere. CO2-based fuels are produced via the so-called "power-to-fuel" approach enabling the production of hydrocarbon fuels (e-fuels) using CO2 and green H2, i.e. hydrogen generated by the electrolysis of water with renewable energy (e.g. Breyer et al., 2015, Sternberg and Bardow, 2015, Dimitrou et al., 2015, Fasihi et al., 2017, Shih et al. 2018, Anwar et al., 2020). Artz et al., 2019 have shown that the largest reduction in the absolute amount of greenhouse gas emissions could be achieved by coupling of highly concentrated CO2 sources from CO2-emitting sectors with carbon-free hydrogen or electrons from renewable power via this approach. . Biogenic CO, H2 (Syngas) or CO2 from biomass conversion can also complete those resources reducing again the carbon intensity of the CCU product while valorizing thoses molecules (Ostadi et al., 2019) When it comes to alternative fuels, CO2-based fuels should be considered as a drop-in solution. Even with all possible efforts to reach the 2030 emission targets, the current gas infrastructure worldwide will not allow for a fast and global deployment of an hydrogen economy in the transport, energy and industrial sectors (e.g. Muratori et al., 2018, Gumber and Gurumoorthy, 2018). In contrast, e-CH4 can be used with the current natural gas infrastructure, especially in the energy and high heat industrial sectors (Deutz et al., 2018, Ram et al., 2020). In the transport sector, e-CH4 might not be the best solution as leaks are likely to occur, but methanol could be used efficiently with the existing infrastructures, especially for aviation and shipping (Schemme et al, 2017). At short-term, the role of hydrogen would first be to form methanol or other	duplicate of 60459	Christian Breyer	LUT University	Finland
28953	58	1	58	1	Please substitute the reference to Gül 2020 with the first reference that outlined the power-gas-concept Sterner (2009): Bioenergy and renewable power methane in integrated 100% renewable energy systems	accepted; added reference	Fabian Heymann	INESC TEC	Switzerland
52221	58	2	58	5	Run-on sentence	Taken into account. The section is updated:"Power to fuels (PtX). The process of using electricity to generate a gaseous fuel, such as hydrogen or ammonia, is termed power-to-gas (P2G) (Gül et al. 2020) and injected to the existing gas infrastructure (section 6.4.5), with the added benefit of decarbonizing gas (Brandon et al. 2015), and combined cycle gas turbines can be converted to run on hydrogen. For greater compatibility with existing gas systems and appliances, the hydrogen can be methanated using captured carbon (Thema et al. 2019) (i.e., synthetic fuels), however methane has high global warming potential and its supply chain emissions have been found to be significant (Balcombe et al. 2013)."	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
78815	58	2	58	5	Old ref and text to adapt : global warming potential of methane is not the topic of this chapter dedicated to fuel Power to X (CO2 based-fuels) synthesis. Methane is not dedicated to be released in the atmosphere but dedicated to gas network for heating, cooling, (Henni et al., 2021, Applied Energy, 288, 116597). The base of the problem is to stop putting fossil carbon to the atmosphere so in producing methane via power-to-gas, it is recycled methane that is injected through the infrastructure, so it will anyway decrease the amount of fossil carbon to the atmosphere. CO2-based fuels are produced via the so-called "power-to-fuel" approach enabling the production of hydrocarbon fuels (e-fuels) using CO2 and green H2, i.e. hydrogen generated by the electrolysis of water with renewable energy (e.g. Breyer et al., 2015, Sternberg and Bardow, 2015, Dimitrou et al., 2015, Fasihi et al., 2017, Shih et al. 2018, Anwar et al., 2020). Artz et al., 2019 have shown that the largest reduction in the absolute amount of greenhouse gas emissions could be achieved by coupling of highly concentrated CO2 sources from CO2-emitting sectors with carbon-free hydrogen or electrons from renewable power via this approach. . Biogenic CO, H2 (Syngas) or CO2 from biomass conversion can also complete those resources reducing again the carbon intensity of the CCU product while valorizing thoses molecules (Ostadi et al., 2019) When it comes to alternative fuels, CO2-based fuels should be considered as a drop-in solution. Even with all possible efforts to reach the 2030 emission targets, the current gas infrastructure worldwide will not allow for a fast and global deployment of an hydrogen economy in the transport, energy and industrial sectors (e.g. Muratori et al., 2018, Gumber and Gurumoorthy, 2018). In contrast, e-CH4 can be used with the current natural gas infrastructure, especially in the energy and high heat industrial sectors (Deutz et al., 2018, Ram et al., 2020). In the transport sector, e-CH4 might not be the best solution as leaks are likely to occur, but methanol could be used efficiently with the existing infrastructures, especially for aviation and shipping (Schemme et al, 2017). At short-term, the role of hydrogen would first be to form methanol or other	duplicate of 60459	Sylvain Nizou	CEA	France
51133	58	6	58	7	"While the roundtrip efficiency of converting electricity to fuel and back again can be low": I agree but this statement is too vague, please be quatitative, and ensure consistence between the figure you will provide here and the figures given in table 6.4 (30-65% which appears to mee surprinsingly hugh figures, and not my definition of 'low" roundtrip efficiency as I stressed in a prevvious comment)	Thanks for this. The values are checked again. Due to recent developments in hydrogen production technologies as well as projections for the future (e.g., SOECs; see section 6.4.5), the efficiency can be higher. The sentence is updated:"PtX can provide all required grid services, depending on how it is integrated. However, not significant amount of PtX is required for storage in order to produce electricity again (Bogdanov et al., 2019) due to the low roundtrip efficiency of converting electricity to fuel and back again, however there is significant need for distributable fuels (hydrogen, methane, ammonia, synthetic hydrocarbons), for example in energy systems lacking the potential for renewables and/or many applications requiring the high energy density of chemical storage, such as transport of heavy goods and heating/cooling of buildings (Gül et al. 2020). "	Eric PROUST	European Nuclear Society (ENS)	France
85029	58	6	58	12	power to H and to synthetic fuels using sustainable carbon sources can deliver these functions.see comments 18 to 26.	Thanks for this - This has been investigated in section 6.4.5. Due to space limit, we were not able to address here.	Roque Pedace	UBA.Buenos Aires University	Argentina

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
21023	58	7	58	7	About "[...] to fuel and back again can be low": In table 6.4, a value of 30-65% is given. Is that low ? Please be quantitative and make sure to be consistent with the tale.	rejected; it is low, given that batteries are at 95% and up	Government of France	Ministère de la Transition écologique et solidaire	France
21025	58	13	58	13	The distinction with what is described in the previous section is unclear. In fact, the production of H2 is explicitely mentioned in the previous section. This must be clarified	rejected	Government of France	Ministère de la Transition écologique et solidaire	France
71625	58	13	58	32	Hydrogen should be explain earlier (e.g. after batteries) as it is one of the most promising long term options for deep decarbonisation of industry and transport. Additionally it can provide additional flexibility and storage to the power system.	Rejected. the order has nothing to do with priority	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
74201	58	13	58	32	This section should be amended to include a discussion about the significant investment being made to demostrate the use of nuclear power to generate green hydrogen. https://www.fchea.org/in-transition/2020/5/11/using-nuclear-power-to-produce-green-hydrogen	rejected; limited space	Jeffrey Merrifield	Pillsbury Law Firm	United States of America
75855	58	13	58	32	Perhaps mention that reversible fuel cells only have about 25% of the electrolyzer capacity as fuel cell [13] [13] https://hydrogeneurope.eu/sites/default/files/20200703%20Final%20Draft%20updated%20SRIA%20HE-HER.pdf	rejected; reference not found	Herib Blanco	International Renewable Energy Agency (IRENA)	Germany
85031	58	13	58	31	RHFC are key for integrating electricity , H2 And synthetic fuels	accepted; p58, line 22-23	Roque Pedace	UBA.Buenos Aires University	Argentina
55749	58	19	58	19	"An electrolyser uses excess electricity": the word "excess" can be removed.	accepted; done	Government of United States of America	U.S. Department of State	United States of America
69587	58	19	58	20	Would suggest deleting "excess" in this sentence. Electrolysers use electricity to split water… The concept of using "excess" electricity, whatever the definition of "excess" might be, is unduly restrictive.	duplicate of 55749	Cédric PHILIBERT	Institut Français des Relations Internationales	France
51381	58	22			electricity and heat (Elzinga et al. 2014). Reversible hydrogen fuel	accepted; done	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
84177	58	22	58	23	I completely disagree with the sentence in row 22-23 “Reversible hydrogen fuel cells (RHFCs) can perform both functions in a single device, however they are still in the pre-commercial stage, due to prohibitive production costs.” Please read the following updated references and modified the sentence appropriately: - Martin Tengler, BloombergNEF, 2020, “Green Hydrogen: Time to Scale Up” [available at <https://www.fch.europa.eu/sites/default/files/FCH%20Docs/M.%20Tengler_ppt%20%28ID%2010183472%29.pdf >], - IRENA, “Green hydrogen cost reduction Scaling up renewables to meet the 1.5o C climate goal”, December 2020, [available at <https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Dec/IRENA_Green_hydrogen_cost_2020.pdf>] and - Hydrogen Council and McKinsey & Company, “Hydrogen Insights 2021: A Perspective on Hydrogen Investment, Deployment and Cost Competitiveness” [available at <https://hydrogencouncil.com/wp-content/uploads/2021/02/Hydrogen-Insights-2021.pdf>].	rejected: even the IRENA reference cited says " Reversible PEM or Alkaline technologies exist, but are much less efficient and more complex, and have not being commercially demonstrated yet. Reversible operation also compromises durability"	Mario Valentino Romeri	Independent consultant	Italy
28521	58	24	58	28	The capacity of hydrogen to play a role in decarbonisation is entirely dependent on how it is produced. The first sentence, as it is, does not clarify this and risks therefore to be very misleading. The last sentence ("Hydrogen provides resilience in future low carbon energy systems, covering windless gaps in renewable generation") applies to storage technologies in general, and not just to hydrogen. This should be clarified.	rejected, limited space; the text specifically refers to hydrogen production through electrolysers	Pierpaolo Cazzola	International Transport Forum	France
51383	58	28			covering times without wind and sun for renewable generation	accepted; done	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
52223	58	28	58	28	The use of the term resilience is not correct; security of supply is more appropriate.	Taken into account. The sentence is updated:"Hydrogen can provide long duration storage to deal with prolonged extreme events (e.g., very low output of wind generation) to support resilience of future low carbon energy systems. "	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
55751	58	29	58	32	Recommend rewording these sentences to remove the 80% statistic, which is not realistic in the near term: "Research and development on hydrogen and fuel cell technologies is focused on reducing capital cost (e.g., through innovations in materials, such as membranes and catalysts, and development of infrastructure supply chain), improving efficiency (e.g., through use of high-temperature heat or breakthrough liquefaction technologies), and improving reliability of emerging concepts." No need to mention photo-electrolysis but, if authors elect to do so, consider rephrasing as: "Methods of hydrogen production that are currently in early stages of research include photoelectrochemical (PEC) and thermochemical technologies, which use sunlight and high-temperature heat to produce hydrogen from water."	accepted; done	Government of United States of America	U.S. Department of State	United States of America
7871	58	34	58	35	Public awareness knowledge about electricity storage technologies, their current state, and potential 35 role in future energy systems is limited -- a potential reference to evidence this statement coud be: Jones et al. 'Understanding lay-public perceptions of energy storage technologies: Results of a questionnaire conducted in the UK' https://www.sciencedirect.com/science/article/pii/S1876610218305800	Taken into account. The reference is added	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
9525	58	34	58	42	This section would benefit from some citations of social science research to support the points made.	Taken into account. new references are added to the section:"Public awareness knowledge about electricity storage technologies, their current state, and potential role in future energy systems is limited (Jones et al. 2018). For instance, people do not perceive energy system flexibility and storage as a significant issue or assume storage is already taking place. Public perceptions differ across storage technologies. Hydrogen is considered a modern and clean technology, but people also have safety concerns. Moreover, the public is uncertain about hydrogen storage size and the possibility of storing hydrogen in or near residential areas (Eitan, A. and Fischhendler, I., 2021). Battery storage both on household and community level was perceived as slightly positive in one study However, financial costs are seen as a main barrier (Ambrosio-Albala, P et al., 2020). The potential of electric vehicle batteries to function as flexible storage is limited by the current numbers of EV owners and concerns that one's car battery might not be fully loaded when needed."	Patrick Devine-Wright	University of Exeter	United Kingdom (of Great Britain and Northern Ireland)
17517	58	34	58	42	please provide reference to this paragraph. Thanks	Taken into account. The reference is added:(Eitan, A. and Fischhendler, I., 2021).	Alaa Al Khourdajie	IPCC	United Kingdom (of Great Britain and Northern Ireland)
37713	58	34	58	35	Limited public knowledge in this area is the result of false narratives created by reports which fail to prominently mention drawbacks of storage. At least, in this report it should be corrected.	Taken into account. Thanks for this. New references are added to this section to support our claim. Unfortunately, due to space limit we are not able to expand further:"new references are added to the section:"Public awareness knowledge about electricity storage technologies, their current state, and potential role in future energy systems is limited (Jones et al. 2018). For instance, people do not perceive energy system flexibility and storage as a significant issue or assume storage is already taking place. Public perceptions differ across storage technologies. Hydrogen is considered a modern and clean technology, but people also have safety concerns. Moreover, the public is uncertain about hydrogen storage size and the possibility of storing hydrogen in or near residential areas (Eitan, A. and Fischhendler, I., 2021). Battery storage both on household and community level was perceived as slightly positive in one study However, financial costs are seen as a main barrier (Ambrosio-Albala, P et al., 2020). The potential of electric vehicle batteries to function as flexible storage is limited by the current numbers of EV owners and concerns that one's car battery might not be fully loaded when needed.""	Ravi B Grover	Homi Bhabha National Institute	India

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
55753	58	34	58	42	This paragraph could be deleted. If retained, consider rephrasing as: "Public awareness about electricity storage technologies, their current state, and potential role in future energy systems is limited. Concerns that are commonly articulated include hydrogen safety, cost of energy storage, and impacts of electric vehicle integration with the grid on battery reliability. Outreach and R&D are both needed to address these concerns."	Taken into account. Thanks for this - the current section is improved.	Government of United States of America	U.S. Department of State	United States of America
52225	58	40	58	40	Missing "as" between "seen" and "a".	Fixed	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
80477	58	40	58	40	Add a reference to the statement “Battery storage both on household and community level was perceived as slightly positive in one study.”?	The reference is added:"(Ambrosio-Albala, P et al., 2020). "	Moritz Riede	University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
64289	58	43	58	46	Mitigation options also include the upgrading of infrastructure along the energy value chain. For example, gas pipelines are often associated with large volumes of ventd emissions which could easily be avoided. In March 2021, a study published on the ESA webpage showed that several methane emission events could be detected around pipeline installations in Russia and other countries (https://www.esa.int/Applications/Observing_the_Earth/Copernicus/Sentinel-5P/Monitoring_methane_emissions_from_gas_pipelines).	Taken into account. in Page 58, line 43-46, the relevance to this comment is not there. However, as mentioned in this section, since the focus is on hydrogen, the following is presented: "In the UK, in the Iron Mains Replacement Programme (CCC 2018), the existing low pressure gas distribution pipes are being converted from iron to plastic for health, safety, and environmental reasons. Gasunie in Netherlands has used an existing 12km natural gas pipeline for transporting hydrogen. In order to transport hydrogen in medium/high-pressure networks, reinforcements in compressor stations and pipeline construction routes (~0.13 €/kg/1000km (Wang et al. 2020)) are required (Gasunie 2019). Yet, new pipelines for hydrogen transmission at national level are likely to be required, which would require investment in the transport infrastructure."	Christian Lelong	Kayrros	United Kingdom (of Great Britain and Northern Ireland)
51385	58	44			The linkage between energy supply and distribution, on the	Fixed	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
71627	58	44	58	46	Introduction to the chapter 6.4.5. is missing as for example in chapter 6.4.4. Transformation challenges for energy infrastructure, transmission and transport should be explained, e.g. stronger electricification, large distances between supply and demand, new energy carriers	Taken into account. This sentece is updated:"As the energy system evolves (e.g., due to electrification, large distances between supply and demand, new energy carriers), the way that energy is transported will also evolve." however, due to space limit we are not able to explain more.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
74785	58	49	58	52	I will suggest that this section should be revised as well for more coherence	Taken into account. The text in this section is improved siginificantly.	Semilore Abikoye	Department of Chemical Engineering, University of Cape Town	South Africa

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
4129	59	1	59	1	Both Section 6.4.5.1 and Box 6.7 (Page 89, L.15) are describing hydrogen technology and overlapping. Isn't it better to integrate into one section?	Rejected. Thanks for the suggestion, however it may not be approproate to change the structure.	Tatsuki Ueda	National Agriculture and Food Research Organization	Japan
9527	59	1	59	1	I did not spot any text on social acceptance or public perceptions of hydrogen in this section, which is a shame as there has been some good social science research conducted on this important topic, for example: Scott and Powells, 2020: https://doi.org/10.1016/j.erss.2019.101346	Taken into account. The following is added to the text : "Furthermore, it is necessary to consider the public perception and social acceptance of deployment of hydrogen technologies and infrastructure (Scott & Powells., 2020), as it could result in costly delays and enforced changes with respect to initial plans (Iribarren et al., 2016))."	Patrick Devine-Wright	University of Exeter	United Kingdom (of Great Britain and Northern Ireland)
28523	59	1	59	4	Hydrogen is not a fuel, but an energy carrier. It is not "one of the key low-carbon energy fuels". Its characteristics with respect to carbon intensity depend heavily on the way it is produced. The title and the first sentence are therefore very misleading, if kept as it is.	Taken into account. The sentence has been updated to avoid confusion:"Hydrogen (H2) is considered to be one of the key energy carriers in future low-carbon energy systems (Nozari and Karabeyoğlu 2015). "	Pierpaolo Cazzola	International Transport Forum	France
64617	59	1	59	1	Section 6.4.5.1 is misleading, already in the title, and confirms popular misunderstanding about hydrogen as climate-friendly panacea. Only late in the day (from l. 20) is it mentioned that hydrogen can be produced from a range of high- and low-carbon sources. Initially it is called low-carbon and emission-free, which makes little sense while the vast majority of hydrogen used today is produced from fossil fuels without CCS and therefore indirectly emits GHGs in large amounts per unit energy. The section should be rewritten to stress that hydrogen is a secondary energy carrier, just like elecricity, ammonia, methanol etc. Thus with associated GHG emissions depending upon the production chain used.	Taken into account. The sentence has been updated to avoid confusion:"Hydrogen (H2) is considered to be one of the key energy carriers in future low-carbon energy systems (Nozari and Karabeyoğlu 2015)."	Government of Netherlands	Ministry of Economic Affairs and Climate Policy	Netherlands
74203	59	1	62	1	This section fails to discuss the potential to use nuclear power, both current and future units, for the production of green hydrogen.	Taken into account. The sentence has been updated: "from low/zero carbon energy sources such as renewables and nuclear using high temperature reactors (Jaszczur et al. 2016) in electrolysis process (Schmidt et al. 2017a) and thermochemical water splitting (EERE 2020)"	Jeffrey Merrifield	Pillsbury Law Firm	United States of America
84351	59	1	63	21	Ill-structured. Start from figure 6.18! The Life Cycle Assessment issue is not addressed, especially regarding the refurbishement of existing industrial capabilities.	Taken into account. The section from Ammonia; promosing… is improved and the title is changed to "Hydrogen Energy Carriers". The topic of LCA is interesting and important. However, space limits prevent us from addressing it here	Vincent MAZAURIC	Schneider Electric	France
85347	59	1	59	1	The section on hydrogen needs to engage with Australias Hydrogen strategy and the Chief Scientist reports and National Hydrogen Roadmap. However chief constraints are government's preference for coal subsidies. Germany also has a national Hydrogen Strategy 2020.	Taken into account. The following is added to the text: Australia sets a vision for an innovative, safe and clean hydrogen industry (Australia's Hydrogen strategy, 2020) referring to both 'clean renewable' hydrogen and 'CCS based' hydrogen. In 2020, German government announced national hydrogen strategy, which includes green hydrogen produced from RES as well as supporting Power-to-X (PtX) technologies (Mitsui & Co., 2020).	Linda Hancock	Deakin University	Australia

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
85349	59	1	61	40	a significant issue for hydrogen is the source of the fuel. This is highlighted in the comparison in australia of brown blue and green hydrogen and the fact that blue with CCS may risk being a stranded asset eg as Japan becomes more adamant about a green supply chain eg.2021 Hancock, L. and Ralph, N. A framework for assessing fossil fuel 'retrofit' hydrogen exports: Security-justice implications of Austalia's coal-generated hydrogen exports to Japan, Energy, 4 February, vol 223, 15 May 2021, 119938	The following is added to the text: Hydrogen production costs are highly dependent on cost of core resources (i.e., fossil fuel resources for producing 'blue' hydrogen and zero/low carbon electricity sources for production of 'green' hydrogen). Australia sets a vision for an innovative, safe and clean hydrogen industry (Australia's Hydrogen strategy, 2020) referring to both 'clean renewable' hydrogen and 'CCS based' hydrogen. In 2020, German government announced national hydrogen strategy, which includes green hydrogen produced from RES as well as supporting Power-to-X (PtX) technologies (Mitsui & Co., 2020). However, due to space limit we were unalbe to expand further.	Linda Hancock	Deakin University	Australia
62003	59	2	59	2	Typo: subscript, change "Hydrogen (H2) is considered" to "Hydrogen (H2) is considered"	Fixed	Esa Vakkilainen	LUT University, Lappeenranta	Finland
64139	59	2	60	3	Hydrogen production processes and its production cost comparison may be placed in Section 6.4.2 (Energy Sources and Energy Conversion) alongwith other energy carriers. Here, in this section 6.4.5 (Energy Transport and Transmission), hydrogen transport issues and costs may be discussed.	Rejected. Thanks for the suggestion, however it may not be approproate to change the structure.	Ghulam Rasul Athar	Pakistan Atomic Energy Commission	Pakistan
69593	59	2	59	2	A number of analysts have expressed a more restrictive vision of the possible role of hydrogen in the path to net zero emissions, with a focus on decarbonising chemicals and steel, delivering a carbonlesss fuel, ammonia, to deep sea shipping, and A carbon-low fuel, e-kerosene, to aviation, and finally supporting back-up and international trade functions in power systems. See, e.g. Liebreich, M. 2019, Separating Hype from Hydrogen, Part One and Part Two; Philibert, C. 2020, Perspectives on a hydrogen strategy for the European Union, Insitut Français des Relations Internationales.	Taken into account. he following is added to the text: In particular, hydrogen is expected to be applied in areas that are difficult to decarbonize, such as aviation, chemical feedstock, heavy duty transport, etc. (BloombergNEF, 2020).	Cédric PHILIBERT	Institut Français des Relations Internationales	France
71629	59	2	59	2	Recommendation to define hydrogen as an energy carrier and not as a fuel	Fixed	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
71631	59	2	59	19	Paragraph lists the current application fields for hydrogen and the possible applications in the future. It could be improved by priotizing applications fields and indicating which application sectors are difficult to decarbonise without hydrogen, e.g. aviation, chemical feedstock, heavy duty transport.	Taken into account. The following is added to the text: In particular, hydrogen is expected to be applied in areas that are difficult to decarbonize, such as aviation, chemical feedstock, heavy duty transport, etc. (BloombergNEF, 2020).	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
74851	59	2	59	2	Hydrogen H2 should be H2	Fixed	Government of Kenya	Kenya Meteorological Service	Kenya
5367	59	3	59	3	After "décarbonized future", add: as long as it is produced by non CO2 emitting systems.	Taken into account. This sentence has been updated:"Hydrogen at scale could offer a versatile, clean, and flexible energy carrier when produced by low/zero CO2 emitting systems (Fuel Cells and Hydrogen Joint Undertaking 2019). "	Michel SIMON	Retraité/ Pdt d'association	France
45501	59	3	59	3	sentence is not correct	Fixed	Kornelis Blok	Delft University of Technology	Netherlands
63177	59	3			Need to remove "at"	Fixed	Jennifer Sklarew	George Mason University	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
18243	59	4	59	4	(Section 6.4.5.1) "Hydrogen is carbon free" - misses the importance of carbon / GHG emissions in the production of hydrogen. Suggest rewording to make clear this is a statement regarding chemistry, not the use of hydrogen in the economy.	Taken into account. This sentence is updated:"Hydrogen can be utilized for provision of electricity, heat, transport, industrial demand and energy storage. "	Government of United Kingdom (of Great Britain and Northern Ireland)	Department for Business, Energy & Industrial Strategy	United Kingdom (of Great Britain and Northern Ireland)
21027	59	4	59	4	Stating that 'Hydrogen is Carbon-free' is the same as stating that electricity is Carbon free. It depends how it is produced. Most of current hydrogen production is NOT carbon free	Taken into account. To avoid confusion this sentence is updated:"Hydrogen can be utilized for provision of electricity, heat, transport, industrial demand and energy storage. "	Government of France	Ministère de la Transition écologique et solidaire	France
21029	59	4	59	4	High must be quantified	Taken into account. To avoid confusion this sentence is updated:"Hydrogen can be utilized for provision of electricity, heat, transport, industrial demand and energy storage. "	Government of France	Ministère de la Transition écologique et solidaire	France
55755	59	4	59	4	"Hydrogen is carbon-free and has a high conversion efficiency": Recommend deleting this sentence. The low-carbon trait is mentioned in the preceding sentence. The conversion efficiency might confuse readers. Round-trip efficiency of hydrogen pathways is not always high, and the conversion efficiency is only relevant in the context of the end-use. If retained, provide context.	Taken into account. To avoid confusion this sentence is updated:"Hydrogen can be utilized for provision of electricity, heat, transport, industrial demand and energy storage. "	Government of United States of America	U.S. Department of State	United States of America
60139	59	4	59	4	Hydrogen at could offer a versatile, clean, and flexible (remove at ??)	Fixed	Umasankari Kannan	Bhabha Atomic Research Centre	India
10949	59	6	59	6	make clear the sentence "industry, transport storage"	Fixed	Dong-Woon NOH	Korea Energy Economics Institute	Republic of Korea
16373	59	6	59	6	make clear the sentence "industry, transport storage"	fixed	Government of Republic of Korea	Korea Meteorological Administration (KMA)	Republic of Korea
69589	59	7	59	7	Refining and chemicals producction, notably ammonia and methanol, are the two largest current uses of hydrogen (see IEA 2019 The Future of Hydrogen)	Taken into account. The sentece has been updated: "Currently, hydrogen has limited applications mainly in production of methanol and ammonia (IEA, 2019)"	Cédric PHILIBERT	Institut Français des Relations Internationales	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
84179	59	8	59	9	I very much appreciated the sentence in row 8-9 “Furthermore, there are currently about 80 fuel cell power plants operating in the U.S. with a total of about 190 MW of electric generation capacity (EIA 2020)” because it is a rare finding that hydrogen fuel cell production plants are currently already in operation in the power generation sector. But I suggest to update the sentence with the following text “Furthermore, as of the end of October 2020, there were about 161 operating fuel cells at 108 facilities in the United States with a total of about 250 megawatts (MW) of electric generation capacity. The largest is the Red Lion Energy Center in Delaware with about 25 MW total electric generation capacity, which uses hydrogen produced from natural gas to operate the fuel cells.” Same reference: EIA, “Hydrogen explained Use of hydrogen - Hydrogen fuel cells produce electricity” [available at < https://www.eia.gov/energyexplained/hydrogen/use-of-hydrogen.php > accessed March 2021] In recent years I published different papers with regard of possible use of hydrogen fuel cells as electric generation plant. In particular, in my studies I assessed the economic possibility (in LCOE terms, in hypothesis of fuel cell vehicles mass production) to use an Hydrogen Fuel Cells Powertrain as Power Generation Plant obtaining surprisingly and positive results. In my analysis the economic advantage ‘to consider an H2FCPowertrain as power generation plant’ and related possible long-term effects in power generation are confirmed year after year. In my analysis I found that the adoption of Hydrogen Fuel Cells Powertrain as Power Generation Plant could have relevant long-term effects in the power generation sector. In my 2019 study I wrote: “As I underlined in my 2018 study: “Thanks to the introduction and use of H2FCPowertrains as power plants, considering the low level of Overnight Cost, it seem to be possible to think that the present capital intensive profile of the Power Generation Sector could change gradually. In terms of plant Lifetime, the H2FCPowertrain appears poor (also considering the DOE target of 8000 hours lifetime) if compared either to the other generation technologies or to the U.S. DOE CHP target (80000 hours). But, in a long term investment perspective, it is possible to foresee a	Rejected. Thanks for this. The text is updated. Regarding the H2FC power trains, the topic is interesting and important, however space limit prevents us to explain further.	Mario Valentino Romeri	Independent consultant	Italy
69591	59	9	59	11	This is a very narrow description of the Japanese Hydrogen Strategy. The largest foreseen consumption of Hydrogen in Japan in the coming decades is for combustion in power thermal plants, starting with ammonio co-combustion in coal plants. See GoJ? 2017 Basic Hydrogen Strategy (https://www.meti.go.jp/english/press/2017/1226_003.html), and Jera 2020 NZE strategy (https://www.jera.co.jp/english/corporate/zeroemission)	Taken into account. The sentence is updated: "The Japanese government has invested in development of hydrogen fuel infrastructure, as a part of hydrogen economy (METI 2017), aimed at facilitating large scale deployment of hydrogen-based fuel cell vehicles as well as hydrogen combustion in thermal power plants, starting with ammonia co-combustion in coal plants (JERA, 2020). "	Cédric PHILIBERT	Institut Français des Relations Internationales	France
69603	59	11	59	25	Please do not introduce a paragraph on ammonia with "captured CO2", which is needed for methanol or synthetic HCs but precisely not for ammonia, which contains no carbon atom. Indeed this entire paragraph should go to another place.	Taken into account. To avoid confusion, the sentence is updated:"Hydrogen could be used to produce synthetic fuels (hydrogen based PtX products) such as ammonia, synthetic methane, and synthetic hydrocarbons (IRENA 2019d)."	Cédric PHILIBERT	Institut Français des Relations Internationales	France
69605	59	12	59	12	"Synthetic oil products" is an oxymoron. "Synthetic hydrocarbons" should be used instead.	Fixed	Cédric PHILIBERT	Institut Français des Relations Internationales	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
69597	59	15	59	17	The idea of using hydrogen for transporting energy from areas with large renewable resources was first expressed in the early 1980's by Reinhard Dahlberg , the Head of the semiconductor department of Telefunken. It was more recently re-inserted in the decarbonisation discussion by Philibert, C. 2017 Renewable Energy for Industry, IEA Insight Papers, then picked up by the Adair Turner and the Energy Transition Commission in its 2018 publication, Mission Possible.	Taken into account. (Philibert 2017) is added to the text.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
28527	59	16	59	19	Hydrogen could indeed replace natural gas-based electricity generation, at very high costs in terms of energy efficiency losses. The energy efficiency cost (no matter the way hydrogen is produced in the first place: this applies to all cases) should clearly be flagged, here. This is also the case for the sentence referring to its role to "balance variable renewable generation and demand" (something for which hydrogen is in competition with other technologies/solutions, as already flagged earlier).	Thanks for this - Many companies such as Siemens are making the avaialble gas turbines, to run by 100% hydrogen, pls see: https://www.siemens-energy.com/global/en/news/magazine/2019/hydrogen-capable-gas-turbine.html and https://www.powermag.com/siemens-roadmap-to-100-hydrogen-gas-turbines/	Pierpaolo Cazzola	International Transport Forum	France
64255	59	16	59	27	Indeed, zero-carbon (so-called “green” H2) hydrogen can be produced from either renewables or nuclear (two main low-carbon technologies) by splitting water into hydrogen and oxygen, namely: (1) Electrolytic processes for water splitting Like fuel cells, electrolyzers are based on electrical processes and consist of an anode and a cathode separated by an electrolyte. This technology is well developed and available commercially. Alkaline electrolyzers operate via transport of hydroxide ions (OH-) through the electrolyte from the cathode to the anode with hydrogen being generated on the cathode side. In a “polymer electrolyte membrane” (PEM) electrolyzer, the electrolyte is a solid specialty plastic material (transport of positively charged hydrogen ions /protons/). (Source : https://www.energy.gov/eere/fuelcells/hydrogen-production-electrolysis) (2) Thermochemical water splitting Thermochemical water splitting uses high temperature heat (500°–2,000°C) —from concentrated solar power or from the waste heat of nuclear power reactions—and chemical reactions to produce hydrogen and oxygen from water. This is a long-term technology pathway, with potentially low or no greenhouse gas emissions. Source : US-DOE website - https://www.energy.gov/eere/fuelcells/hydrogen-production-thermochemical-water-splitting	Taken into account. The sentence has been updated: "from low/zero carbon energy sources such as renewables and nuclear using high temperature reactors (Jaszczur et al. 2016) in electrolysis process (Schmidt et al. 2017a) and thermochemical water splitting (EERE 2020)"	Georges VAN GOETHEM	Royal Academy of Overseas Sciences (ARSOM - KAOW)	Belgium
69607	59	16	59	16	Only synthetic methane can "benefit" from the LNG industry. But all products mentioned here are much easier to store than hydrogen… synthetic methane still being the least easy of them.	Taken into account. To avoid confusion the sentence is updated:"(a) they can be used in existing infrastructure in the energy intensive industries and in the transport sector (Schemme et al. 2017; Transport and Environment 2018; DENA 2017; IRENA2019b), and (b) it is easier to store than hydrogen. "	Cédric PHILIBERT	Institut Français des Relations Internationales	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
61799	59	17	59	19	"Hydrogen could also provide long-term storage in order to deal with extreme events, such as low output of renewable generation for long durations or a significant increase in demand driven by extreme weather conditions." This seems like a very inefficient and expensive way, as it would be much more economical to simply run a nuclear power plant with a very high availability. While using hydrogen for storage is certainly possible, a comparison to other options – and their respective costs and benefits – needs to be made to give the overall picture of the options available. Often the studies which have need for balancing high shares of VRE's a priori exclude nuclear and therefore needlessly limit the solutions available in the real world.	Taken into account. We appreciate this comment. The balance between use of nuclear for hydrogen pruduction and hydrogen transport should be investigated. However, the sentecne is updated: "Utilizing remote renewable/low carbon sources to produce hydrogen and then transport these fuels over long distances would facilitate cost-effective global energy system decarbonization (high confidence) (See also Box 6.7 and Box 6.8). Electricity generated from renewables (e.g., wind in north of Europe, solar in Africa) could be used to produce hydrogen that would be then transported for use elsewhere (Philibert, 2017; Ameli et al. 2020). Hydrogen in remote areas, however, would require hydrogen transportation over long distances, including local distribution and intermediate storage capabilities needed for hydrogen delivery to the demand centers (e.g., refueling station or power plants) (Office of energy efficiency et al. 2018). Furthermore, large-scale production of hydrogen through nuclear (e.g., Hydrogen2Heysham project (EDF Energy, 2019)) could be beneficial (Lucidcatalyst, 2021), due to: (a) commercially available with proven technology, and (b) widely available feedstock." In this section we presented different options, which in order to do a cost-comparison many factors should be taken into account. The sentence has been updated: "from low/zero carbon energy sources such as renewables and nuclear in thermochemical water splitting using high temperature reactors (Jaszczur et al. 2016, EERE 2020) and electrolysis process (Schmidt et al. 2017a)"	Rauli Partanen	Think Atom	Finland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
65831	59	17	59	19	"Hydrogen could also provide long-term storage in order to deal with extreme events, such as low output of renewable generation for long durations or a significant increase in demand driven by extreme weather conditions." Please provide the round-trip efficiency for solar/wind-power-to-hydrogen-to-power. Then compare the system economy to running a nuclear plant. I find it economically very unlikely that hydrogen would be ever used to balance grid, other than in studies that a priori limit nuclear energy. Revise accordingly.	Taken into account. We appreciate this comment. The balance between use of nuclear for hydrogen pruduction and hydrogen transport should be investigated. However, the sentecne is updated: "Utilizing remote renewable/low carbon sources to produce hydrogen and then transport these fuels over long distances would facilitate cost-effective global energy system decarbonization (high confidence) (See also Box 6.7 and Box 6.8). Electricity generated from renewables (e.g., wind in north of Europe, solar in Africa) could be used to produce hydrogen that would be then transported for use elsewhere (Philibert, 2017; Ameli et al. 2020). Hydrogen in remote areas, however, would require hydrogen transportation over long distances, including local distribution and intermediate storage capabilities needed for hydrogen delivery to the demand centers (e.g., refueling station or power plants) (Office of energy efficiency et al. 2018). Furthermore, large-scale production of hydrogen through nuclear (e.g., Hydrogen2Heysham project (EDF Energy, 2019)) could be beneficial (Lucidcatalyst, 2021), due to: (a) commercially available with proven technology, and (b) widely available feedstock." In this section we presented different options, which in order to do a cost-comparison many factors should be taken into account. The sentence has been updated: "from low/zero carbon energy sources such as renewables and nuclear in thermochemical water splitting using high temperature reactors (Jaszczur et al. 2016, EERE 2020) and electrolysis process (Schmidt et al. 2017a)"	Eero Hirvijoki	Aalto University	Finland
28529	59	20	59	34	Methane pyrolysis is missing from the pathways. It should be added.	Taken into account. The following is added:"...and (e) other processes such as pyrolysis of methane (Sanchez-Bastardo et al., 2020)..."	Pierpaolo Cazzola	International Transport Forum	France
43153	59	20	59	27	There are other 'low carbon' hydrogen production methods / pathways: Steam reforming of light oils with CCS, Gasification of heavy oils with CCS, solar thermo-chemical water splitting and biological hydrogen production (cyanobacteria). Source: Velazquez Abad, A. and P. E. Dodds (2017). Production of Hydrogen A2 - Abraham, Martin A. Encyclopedia of Sustainable Technologies. Oxford, Elsevier: 293-304.	Taken into account. This sentence has been added:"and (e) other processes such as pyrolysis of methane (Sanchez-Bastardo et al., 2020), steam reforming of light oil and gasification of heavy oil with CCS, solar thermo-chemical water splitting, biological hydrogen production (cyanobacteria) (Velazquez Abad and Dodds 2017), and microbes that use light to make hydrogen (under research) (EIA., 2020). "	Abad Velazquez	Transport Research Laboratory	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
48133	59	20	50	20	"Hydrogen can be produced from…" For an analysis of hydrogen production methods, please see Colella, W.G., M.Z. Jacobson, and D.M. Golden, Switching to a U.S. hydrogen fuel cell vehicle fleet: The resultant change in emissions, energy use, and global warming gases, J. Power Sources, 150, 150-181, 2005; and Jacobson, M.Z., W.G. Colella, and D.M. Golden, Cleaning the air and improving health with hydrogen fuel cell vehicles, Science, 308, 1901-1905, 2005	Taken into account. The section has been updated:"Hydrogen can be produced from fossil fuels, biological material, and water (Dodds et al. 2015). Low/zero carbon hydrogen can be produced from: (a) steam methane reforming (SMR) with carbon capture and storage (CCS) (Sanusi and Mokheimer 2019), (b) autothermal reforming (ATR) with CCS (Zhou et al. 2020), (c) coal/biomass gasification with CCS (Hu et al. 2020), (d) from low/zero carbon energy sources such as renewables and nuclear using high temperature reactors (Jaszczur et al. 2016) in electrolysis process (Schmidt et al. 2017a) and thermochemical water splitting (EERE 2020), and (e) other processes such as pyrolysis of methane (Sanchez-Bastardo et al., 2020), steam reforming of light oil and gasification of heavy oil with CCS, solar thermo-chemical water splitting, biological hydrogen production (cyanobacteria) (Velazquez Abad and Dodds 2017), and microbes that use light to make hydrogen (under research) (EIA., 2020)."	Mark Jacobson	Stanford University	United States of America
64181	59	20	59	21	Low carbon hydrogen?	Fixed	Minal Pathak	WGIII TSU, Ahmedabad University	India
69595	59	20	59	25	What is missing here is the technology options for pyrolysis of methane into H2 and solid carbon (no CO2 being formed) technology that has already been proven at commercial scale at the Kvaerner Carbomont Plant in Canada. Monolith Materials is building two plants in the US, the Hazer Group a pilot plant in Western Australia. BASF, TNO, Gazprom are working on various technologiesSee e.g. Philibert, C. 2020, Methane splitting and Turquoise ammonia, 14 May, ammoniaenergy.org.; Parkinson et alii, 2019, Levelized cost of CO2 mitigation from hydrogen production routes, Energy Environ. Sci, 12, 19; Pöyry Management Consulting, 2019, Hydrogen from natural gas - The Kea to deep decarbonisation, etc.	Taken into account. The section has been updated:"Hydrogen can be produced from fossil fuels, biological material, and water (Dodds et al. 2015). Low/zero carbon hydrogen can be produced from: (a) steam methane reforming (SMR) with carbon capture and storage (CCS) (Sanusi and Mokheimer 2019), (b) autothermal reforming (ATR) with CCS (Zhou et al. 2020), (c) coal/biomass gasification with CCS (Hu et al. 2020), (d) from low/zero carbon energy sources such as renewables and nuclear using high temperature reactors (Jaszczur et al. 2016) in electrolysis process (Schmidt et al. 2017a) and thermochemical water splitting (EERE 2020), and (e) other processes such as pyrolysis of methane (Sanchez-Bastardo et al., 2020), steam reforming of light oil and gasification of heavy oil with CCS, solar thermo-chemical water splitting, biological hydrogen production (cyanobacteria) (Velazquez Abad and Dodds 2017), and microbes that use light to make hydrogen (under research) (EIA., 2020)."	Cédric PHILIBERT	Institut Français des Relations Internationales	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
75857	59	20	59	34	It might be useful to add pyrolysis to the list This pathway combines the use of natural gas as feedstock with no CO2 production. The carbon in the methane instead, ends up as solid carbon. A market for carbon black is already existing today, which would provide an additional revenue stream (USD 0.5 – 2/kg of carbon). The existing market is mainly for rubber (tyres) and satisfying such market would be equivalent to about 5 Mt H2 per year (or about 7% of current global production). In the future, new markets such as graphite for batteries, graphene or integration into steel making could arise and in the worst case, the solid carbon can be stored having much lower volumes than CO2. The process uses about 4-5 times less electricity than electrolysis. A disadvantage of this pathway is the quality for both the hydrogen and the carbon. Hydrogen would need further purification to be used in fuel cells. There are various technology options, but they are at the lab or pilot scale. The first commercial demo project has received funding from the Australian Renewable Energy Agency, and it is set to start production in 2021. Companies in Australia, Germany, France, the Netherlands, and Russia are looking into it. [25] DOI: https://doi.org/10.1002/cite.202000021 [26] https://doi.org/10.1016/j.ecmx.2020.100043	Taken into account. The folling sentence is updated:"Currently, there are uncertainties on CCS costs (Roussanaly, S et al., 2020). For natural gas reforming the projections (IEA 2019; Staffell et al. 2018) demonstrate that the CCS will add on average 50% on the capital expenditure (CAPEX) and 10% for fuel as well as 100% of operation expenditure (OPEX), while for coal gasification, the CAPEX and fuel cost is expected to increase (compared to without CCS) 5% and OPEX by 130%. Three main electrolysis technologies are: alkaline, proton exchange membrane (PEM), and solid oxide electrolysis cells (SOECs), where the estimated CAPEX are provided in (IEA 2019; Fasihi and Breyer 2020)."	Herib Blanco	International Renewable Energy Agency (IRENA)	Germany
71633	59	21	59	25	Production routes for hydrogen could be differentiated in technologies from low/zero carbon energy sources and technologies related to CCS. Uncertainties related to CCS should be mentioned and discussed.	Taken into account. The folling sentence is updated:"Currently, there are uncertainties on CCS costs (Roussanaly, S et al., 2020). For natural gas reforming the projections (IEA 2019; Staffell et al. 2018) demonstrate that the CCS will add on average 50% on the capital expenditure (CAPEX) and 10% for fuel as well as 100% of operation expenditure (OPEX), while for coal gasification, the CAPEX and fuel cost is expected to increase (compared to without CCS) 5% and OPEX by 130%. Three main electrolysis technologies are: alkaline, proton exchange membrane (PEM), and solid oxide electrolysis cells (SOECs), where the estimated CAPEX are provided in (IEA 2019; Fasihi and Breyer 2020)."	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
80479	59	21	59	21	The abbreviation “SMR” seems to be used for two different things: “steam methane reforming” and “small modular reactors” --> fix?	Taken into account. We mentioend here as steam methane reforming	Moritz Riede	University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
69599	59	23	59	25	What is the "national transmission system" here? If this is the gas transportation network, it cannot transport liquefied hydrogen, as suggested, but only compressed one.	Fixed.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
69609	59	23	59	24	These numbers seem odd - why such a difference for methanol and for e-methane, hasn't the e-methane the same carbon content than the natural methane - hence the reduction should be entirely linked to air capture or biomass capture.	Correct. To avoid confusion, "in this context" has been added.	Cédric PHILIBERT	Institut Français des Relations Internationales	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
55757	59	24	59	24	Recommend deleting "e.g., High Temperature Reactors" or making the words lower case. Initial caps indicate that it is a specific reactor type (although many reactor types can operate at high temperatures). As written it may confuse people.	Fixed.	Government of United States of America	U.S. Department of State	United States of America
69611	59	26	59	26	To generate electricity ammonia can be co-combused with coal in steam plants, combusted in gas turbines, combusted in engine generators, or used in some fuel cells, notably solid oxyde fuel cells. It's not clear what "direct use" designate, nor what "indirect use" would mean. There is a risk of high NOx in combustion due to the weakness of the bonds N-H (as compared to the triple bond of N2 atoms); however, combustion of H2 takes place at higher temperature and is also at risk of producing substantial NOx emissions. Researchers have already shown various ways to make combustion less emittive of NOx, at levels that could then be brought to very low levels with selective catalytic recirculation (Valera-Medina A. et alii, 2018, Ammonia for power, Progress in Energy Combust. Sci. 69: 63-102; Kobayashi H. et alii, 2018; Science and technology of ammonia combustion, Proc. Combust. Instit; 37: 109-133; Elishav O. et alii, 2020, Progress and Prospective of Nitrogen-Based Alternative Fuels, Chem. Rev. 120: 5352-5436. For selective catalytic recirculation, ammonia itself can be used as a catalyst, as is the case with products such as AdBlue and similar; See e.g. De Vries, N. 2019, Safe and effective application of ammonia as a marine fuel, Thesis for the degree of M.Sc. in Marine Technology, https://repository.tudelft.nl/	Rejected. To deal with NOx emissions, many applications have been undertaken by selective catalytic/non-catalyst reduction, two-stage combustors, and swirl mechanisms (Lamas Galdo 2020; Valera-Medina et al. 2018). The topic is interesting, however due to space limit we are not able to extend further.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
5369	59	27	59	27	delete Renewable at the beginning of line, and replace it by "low carbon sources"	Fixed	Michel SIMON	Retraité/ Pdt d'association	France
71635	59	29	59	32	Cost assumptions uncertainties on CCS should be mentioned. Experiences from demonstration projects and global activities should be included	Taken into account. The folling sentence is updated:"Currently, there are uncertainties on CCS costs (Roussanaly, S et al., 2020). For natural gas reforming the projections (IEA 2019; Staffell et al. 2018) demonstrate that the CCS will add on average 50% on the capital expenditure (CAPEX) and 10% for fuel as well as 100% of operation expenditure (OPEX), while for coal gasification, the CAPEX and fuel cost is expected to increase (compared to without CCS) 5% and OPEX by 130%. Three main electrolysis technologies are: alkaline, proton exchange membrane (PEM), and solid oxide electrolysis cells (SOECs), where the estimated CAPEX are provided in (IEA 2019; Fasihi and Breyer 2020)."	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
75859	59	32	59	34	One recent IRENA report looking into the cost of electrolysis might be a useful reference [27] (also for Table 6.7) [27] https://www.irena.org/publications/2020/Dec/Green-hydrogen-cost-reduction	Taken into account. All the values are checked/updated. Due to couple of comments, table 6.6 and 6.7 are combined in order to make a proper comparison.	Herib Blanco	International Renewable Energy Agency (IRENA)	Germany
69613	59	34	59	34	The second-largest use of ammonia is the manufacturing of mining explosives through ammonium nitrate, then ANFO (ammonium nitrate fuel oil) combination.Is food an "industrial process", and isn't this already covered by the use of ammonia in fertilisers?	Fixed: "At present, major ammonia production is used in fertilizers (~80%), followed by many industrial processes such as manufacturing of mining explosives, and petrochemicals (Jiao and Xu 2018). "	Cédric PHILIBERT	Institut Français des Relations Internationales	France
17381	59	36	59	36	costs of hydrogen produced from wind or solar is missing in Table 6.6	Taken into account. All the values are checked/updated. Due to couple of comments, table 6.6 and 6.7 are combined in order to make a proper comparison.	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
21031	59	36	59	36	Please specify how is the 'efficiency' defined in this table ?	This is updated: LHV	Government of France	Ministère de la Transition écologique et solidaire	France
21033	59	36	59	36	About "1.4-3.9": The principle of CCS is that there is no CO2 emission. So what are those numbers ?	Taken into account. Values are showing the carbon intensity of the value chain of hydrogen production through SMR with CCS. Pls see the reference: Committee on Climate Change, C., 2018: Hydrogen in a low carbon economy.	Government of France	Ministère de la Transition écologique et solidaire	France
21035	59	36	59	36	In the last row of the table, 4th column: I understand that the CCS of biomass has the potential for negative emissions, but then why is the emission of SMR with CCS not zero ?	Taken into account. These values are showing the carbon intensity of the value chain of hydrogen production. Pls see the reference: Committee on Climate Change, C., 2018: Hydrogen in a low carbon economy.	Government of France	Ministère de la Transition écologique et solidaire	France
51387	59	36	60	3	Table 6.6 Can costs/kgH2 be given for the electrolysers to enable comparison with the other technologies?	Taken into account. All the values are checked/updated. Due to couple of comments, table 6.6 and 6.7 are combined in order to make a proper comparison.	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
55759	59	36			For Table 6.6, recommend explaining why SMR costs increase with time and explicitly stating that they are highly dependent on the cost of natural gas, which will vary by region. Also, recommend adding sources. The assumption of 50% for CCS cost should have a reference.	Taken into account. All the values are checked/updated. Due to couple of comments, table 6.6 and 6.7 are combined in order to make a proper comparison. We checked the reference again (CCC, 2018) and we have put the correct values. The reason that I think is the increase of cost of fossil fuels in the future..	Government of United States of America	U.S. Department of State	United States of America
55761	59	36	59	37	These two tables compare hydrogen production options, but they use different scales (2025 and 2030) and different subjective terms (long-term and future) to describe them, which prevents the reader from directly comparing the values.	Taken into account. All the values are checked/updated. Due to couple of comments, table 6.6 and 6.7 are combined in order to make a proper comparison.	Government of United States of America	U.S. Department of State	United States of America
71637	59	36	59	37	Explaination of abreviations is missing	Fixed	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
71639	59	36	59	37	Cost figures for hydrogen from low/zero energy sources is missing	Taken into account. All the values are checked/updated. Table 6.6 and 6.7 are combined in order to make a proper comparison.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
71641	59	36	59	37	Sources of the data in the table is missing	Fixed	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
71643	59	36	59	37	Current, future and long-term as table head lines should be replaced by years valid for the cost figures, technology readiness level and uncertainties related to cost figures should be added	Taken into account. All the values are checked/updated. Due to couple of comments, table 6.6 and 6.7 are combined in order to make a proper comparison.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
55763	59	37	59	37	The biomass-based costs listed here do not appear to align with those on page 43.	Taken into account. We checked this. Their cost is around 2.1 which is not very different than the provided costs here (2.9-5.8). Obviously, due to the uncertanty in the future costs of different technolgies, references provided different values.	Government of United States of America	U.S. Department of State	United States of America
69601	59	38	59	38	"hydrogen is not currently cost effective" means nothing. Green hydrogen or blue hydrogen are currently more expensive than grey or black hydrogen (from NG or coal), which is cost-effective in its current industrial roles. The real question will be which utilisations of low-carbon hydrogen will prove more cost-effective than other decarbonisation options.	Taken into account. The sentence is updated:"Low/zero carbon produced Hydrogen is not currently an option from techno-economic perspectives, but it would have a significant role in future energy systems "	Cédric PHILIBERT	Institut Français des Relations Internationales	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
84181	59				Table 6.6 Key performance and cost characteristics of different hydrogen production technologies	Taken into account. All the values are checked/updated. Due to couple of comments, table 6.6 and 6.7 are combined in order to make a proper comparison.	Mario Valentino Romeri	Independent consultant	Italy
45503	60	1	60	3	Probably the current costs are on the high side. Other cost estimates: Navigant, 2019 (former Ecofys): The optimal role for gas in a net zero emissions energy system, 2019, table 54. BloombergNEF, 2019: Hydrogen - the economics of production from renewables (there may be updates).	Taken into account. Thanks for this. All the values are checked/updated. Due to couple of comments, table 6.6 and 6.7 are combined in order to make a proper comparison. We checked again with the IEA report the values.	Kornelis Blok	Delft University of Technology	Netherlands
55765	60	1	60	1	In Table 6.7, it would be good to define basis for efficiency (e.g., LHV?) and capex. Does this include installation and markup? If not, then the SOEC stack values appear high. Additional references would be valuable. For reference, the following DOE record documents SOEC costs at high volume: https://www.hydrogen.energy.gov/pdfs/20006-production-cost-high-temperature-electrolysis.pdf	Taken into account. All the values are checked/updated. Due to couple of comments, table 6.6 and 6.7 are combined in order to make a proper comparison.	Government of United States of America	U.S. Department of State	United States of America
55767	60	1	60	3	These two tables compare hydrogen production options, but they use different scales (2025 and 2030) and different subjective terms (long-term and future) to describe them, which prevents the reader from directly comparing the values.	Taken into account. All the values are checked/updated. Due to couple of comments, table 6.6 and 6.7 are combined in order to make a proper comparison.	Government of United States of America	U.S. Department of State	United States of America
71645	60	1	60	3	Current and long-term as table head lines should be replaced by years valid for the cost figures, technology readiness level and uncertainties related to cost figures should be added	Taken into account. All the values are checked/updated. Due to couple of comments, table 6.6 and 6.7 are combined in order to make a proper comparison.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
71647	60	1	60	3	Sources of the data in the table is missing	Fixed.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
85033	60	5	60	12	H2 by electrolysis will outperform SMR with CCS.see comment 26. see NREL 2020. See Topsoe SOEC project in denmarkhttps://blog.topsoe.com/haldor-topsoe-joins-ambitious-sustainable-fuel-project-in-denmark.Cost of SOEC 430 U$ according to NREL 2020, as against 500U$in 2050 portrayed in the table page 60.see"Future cost and performance of water electrolysis:An expert elicitation study" O. Schmidt et al 2017	Taken into account. All the values are checked/updated. Due to couple of comments, table 6.6 and 6.7 are combined in order to make a proper comparison.	Roque Pedace	UBA.Buenos Aires University	Argentina
7873	60	7	60	9	The largest reduction in GHG emissions could be achieved by coupling highly-concentrated CO2 sources from CO2-emitting sectors with carbon-free hydrogen or electrons from renewable power in so called “Power-to-fuel” (or Power-to-X) pathways (Artz et al. 2018 -- it depends completely on where the carbon in the CO2 source is from. If it is fossil - this statement is not valid - the largest reductions in GHG emissions cannot be through this route. Would suggest a more nuanced approach here - as Power to X with fossil carbon is not the route to the largest GHG reductions	Taken into account. A largest has been changed to "a significant"	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
61801	60	7	60	8	"The largest reduction in GHG emissions could be achieved by coupling highly-concentrated CO2 sources from CO2-emitting sectors with carbon-free hydrogen or electrons from renewable power". Any electrons from any power source certainly can be used, not just Renewable. Use “Low-carbon power” instead of “renewable power” as it is more scientifically accurate and inclusive and less problematic of a term than “renewable” (see Harjanne and Korhonen, 2018, https://doi.org/10.1016/j.enpol.2018.12.029). Also, literature points out that hydrogen from nuclear can be significantly cheaper than from solar or wind (Kayfeci et al., 2019, https://doi.org/10.1016/B978-0-12-814853-2.00003-5; LucidCatalyst, 2021, https://www.lucidcatalyst.com/hydrogen-report)	Taken into account. The sentence is updated:"However, residual carbon emissions present an important challenge. A significant reduction in GHG emissions could be achieved by coupling highly concentrated CO2 sources from CO2-emitting sectors with carbon-free hydrogen or electrons from low-carbon sources in so called “Power-to-fuel” pathways (Artz et al. 2018)."	Rauli Partanen	Think Atom	Finland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
65833	60	7	60	8	"The largest reduction in GHG emissions could be achieved by coupling highly-concentrated CO2 sources from CO2-emitting sectors with carbon-free hydrogen or electrons from renewable power". Substitute the words "renewable power" with "low-carbon power". Literature points out that hydrogen from nuclear is significantly cheaper than from solar or wind (Kayfeci et al., 2019, https://doi.org/10.1016/B978-0-12-814853-2.00003-5 ; LucidCatalyst, 2021, https://www.lucidcatalyst.com/hydrogen-report).	Taken into account. The sentence is updated:"However, residual carbon emissions present an important challenge. A significant reduction in GHG emissions could be achieved by coupling highly concentrated CO2 sources from CO2-emitting sectors with carbon-free hydrogen or electrons from low-carbon sources in so called "Power-to-fuel" pathways (Artz et al. 2018)."	Eero Hirvijoki	Aalto University	Finland
71649	60	7	60	9	Role of Power-to-Fuel depending on CO2-emitting sectors should be discussed, especially in a long-term zero carbon scenario. Possible sources and related costs for CO2 in the long term should be included e.g. via air separation	Taken into account. The sentence is updated:"However, residual carbon emissions present an important challenge. A significant reduction in GHG emissions could be achieved by coupling highly concentrated CO2 sources from CO2-emitting sectors with carbon-free hydrogen or electrons from low-carbon sources in so called "Power-to-fuel" pathways (Artz et al. 2018).". The topic is interesting and important. However, space limits prevent us from addressing it here	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
33055	60	9	60	12	Another advantage is that SOECs enable the co-electrolysis of steam and CO2 to produce syngas (a mixture of H2 and CO), which can be further processed to obtain valuable fuels such as methane, methanol, dimethyl ether, and others. Furthermore, due to the co-electrolysis of CO2, the oxygen output of SOEC is higher than with the aforementioned alkaline or PEM electrolysis. The produced O2 can be used for medical application [V. Venkataraman et. al., Journal of Energy Storage Volume 24, August 2019, 100782].	Rejected. The topic is interesting and important. However, space limits prevent us from addressing it here	Yashar Hajimolana	University of Twente	Netherlands
12205	60	10	60	10	We would suggest presenting exemples and arguments regarding large scale electrolysers capacities being build near nuclear power plants, functioning in a symbiotic relatiosphip, since the oxygen resulting from the electrolysers can be used in the NPP. Examples such as Hydrogen2Heysham project in the UK which completed the feasibility study in February 2020 and plans to install a 2 MW system comprising AEM and PEM technologies with a capacity to produce 800 kg hydrogen per day connected to Heysham NPP. The argument in favor of large scale electrolyser capacities built in connection to nuclear stations to use off peak electricity can serve to improve the feasibility of the hydrogen economy.	Taken into account. We updated the text regarding nuclear: "Furthermore, large-scale production of hydrogen through nuclear (e.g., Hydrogen2Heysham project (EDF Energy, 2019)) could be beneficial (Lucidcatalyst, 2021), due to: (a) commercially available with proven technology, and (b) widely available feedstock." However due to space limit we are not able to expand further.	Lavinia Rizea	SN Nuclearelectrica SA	Romania
28531	60	13	60	20	This section sounds very optimistic on long distance and high volume transport of hydrogen and fails completely to flag the very significant challenges that need to be overcome to ensure that it can actually happen (even if these challenges do get a mention later in the text). For example, it does not mention the extremely low temperatures (and energy losses) needed to liquefy hydrogen, it doe snot make reference to ammonia and/or liquid organic hydrogen carriers (LOHC). The sentence should be corrected to better reflect these challenges. Page 62, lines 25-26 indicate that "Challenges around hydrogen energy fuels including safety, storage, and consumption, requires new devices and techniques to facilitate large-scale use of hydrogen/ammonia (high confidence)." This is an important element of context that should be brought forward upfront.	Rejected. Thanks for this. As you mentioned that challenges are presented. Although the topic is interesting and important. However, space limits prevent us from addressing it here	Pierpaolo Cazzola	International Transport Forum	France
55769	60	13	60	14	This is an overstatement and confidence is not accurate due to the inclusion of "cost-effective". Technically feasible is accurate, but not the economic statement. See page 6-60, lines 38-39.	Taken into account. The sentence is updated:"Low/zero carbon produced Hydrogen is not currently an option from techno-economic perspectives, but it would have a significant role in future energy systems "	Government of United States of America	U.S. Department of State	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
61803	60	13	60	20	There is no need to exclude remote nuclear powered systems and only mention renewable sources, so replace “Utilising remote renewable energy resources to produce hydrogen…” with “Utilising remote renewable and nuclear energy resources to produce hydrogen…”. In addition, add a nuclear example here: “For example, electricity generated from renewables (e.g., wind in north of Europe and solar in Africa)” for example like this: “For example, electricity generated from renewables or nuclear (e.g., wind in north of Europe, solar in Africa or nuclear energy from a floating, nuclear powered offshore energy platform). See LucidCatalyst, 2021, https://www.lucidcatalyst.com/hydrogen-report) for examples of such concepts.	Taken into account. This section is updated and a separate section regarding nuclear has been added: "Hydrogen in remote areas, however, would require hydrogen transportation over long distances, including local distribution and intermediate storage capabilities needed for hydrogen delivery to the demand centers (e.g., refueling station or power plants) (Office of energy efficiency et al. 2018). Furthermore, large-scale production of hydrogen through nuclear (e.g., Hydrogen2Heysham project (EDF Energy, 2019)) could be beneficial (Lucidcatalyst, 2021), due to: (a) commercially available with proven technology, and (b) widely available feedstock."	Rauli Partanen	Think Atom	Finland
65835	60	13	60	20	If there exists a paragraph promoting hypothetical production and transport of hydrogen from remote locations, then there should be an equivalent paragraph exploring the possibilities of large-scale nuclear-produced hydrogen (LucidCatalyst, 2021,https://www.lucidcatalyst.com/hydrogen-report).	Taken into account. This section is updated and a separate section regarding nuclear has been added: "Hydrogen in remote areas, however, would require hydrogen transportation over long distances, including local distribution and intermediate storage capabilities needed for hydrogen delivery to the demand centers (e.g., refueling station or power plants) (Office of energy efficiency et al. 2018). Furthermore, large-scale production of hydrogen through nuclear (e.g., Hydrogen2Heysham project (EDF Energy, 2019)) could be beneficial (Lucidcatalyst, 2021), due to: (a) commercially available with proven technology, and (b) widely available feedstock."	Eero Hirvijoki	Aalto University	Finland
71651	60	13	60	20	Paragraph could be the first paragraph in chapter 6.4.5.1, remaining text should be alined with texts in box 6.6, box 6.7 and box 6.8	Thanks for the suggestion. Taken into account.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
78633	60	13	60	20	the statement is correct, but may be expanded also to 'hydrogen-based PtX products', as investigated in much detail in a report commissioned by the German Energy Agency: https://www.powerfuels.org/fileadmin/powerfuels.org/Dokumente/Global_Alliance_Powerfuels_Study_Powerfuels_in_a_Renewable_Energy_World.pdf - this is the most detailed study in this field to the knowledge of the reviewer	Fixed.	Christian Breyer	LUT University	Finland
52227	60	14	60	14	Sentence is labeled as high confidence yet has a major qualification of "could". This is inconsistent.	Could is replaced by would	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
62005	60	15	60	15	Typo: change "(See also Box6.7 and Box 6.8)." to "(See also Box 6.7 and Box 6.8)."	Fixed.	Esa Vakkilainen	LUT University, Lappeenranta	Finland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
37715	60	17	60	19	Creating infrastructure for transporting hydrogen will require CAPEX, which countries like India cannot afford. Alternative can be to set up nuclear power plants and hydrogen generation facilities near locations needing hydrogen. This will save CAPEX.	Taken into account. We appreciate this comment. The balance between use of nuclear for hydrogen pruduction and hydrogen transport should be investigated. However, the sentecne is updated: "Utilizing remote renewable/low carbon sources to produce hydrogen and then transport these fuels over long distances would facilitate cost-effective global energy system decarbonization (high confidence) (See also Box 6.7 and Box 6.8). Electricity generated from renewables (e.g., wind in north of Europe, solar in Africa) could be used to produce hydrogen that would be then transported for use elsewhere (Philibert, 2017; Ameli et al. 2020). Hydrogen in remote areas, however, would require hydrogen transportation over long distances, including local distribution and intermediate storage capabilities needed for hydrogen delivery to the demand centers (e.g., refueling station or power plants) (Office of energy efficiency et al. 2018). Furthermore, large-scale production of hydrogen through nuclear (e.g., Hydrogen2Heysham project (EDF Energy, 2019)) could be beneficial (Lucidcatalyst, 2021), due to: (a) commercially available with proven technology, and (b) widely available feedstock." In this section we presented different options, which in order to do a cost-comparison many factors should be taken into account. The sentence has been updated: "from low/zero carbon energy sources such as renewables and nuclear in thermochemical water splitting using high temperature reactors (Jaszczur et al. 2016, EERE 2020) and electrolysis process (Schmidt et al. 2017a)"	Ravi B Grover	Homi Bhabha National Institute	India
2855	60	18	60	20	Would it be more cost effective to transport hydrogen over long distances or to transport another enegy carrier such as Ammonia (NH3)?	Due to the specification mentioned below the figure, ammonia transport is a well-known industry and straight forward.	Leonardo Barreto	Head of center "EU&International"	Austria
55771	60	27	60	27	"Maintaining the security of supply is more challenging: Not sure this is true. Hydrogen is stored in bulk underground caverns today to buffer seasonal differences in supply and demand; each of the three caverns in the U.S. store thousands of tonnes.	This is about the speed of hydrogen transport in order to be delivered on time to the demand centers, and therefore the linepack is required to response to the rapid changes in the network.	Government of United States of America	U.S. Department of State	United States of America
7875	60	28	60	28	A potential explanation of Linepack is in the briefing note from the UK Energy Research Centre: https://ukerc.ac.uk/publications/linepack/ (I am the lead author)	Thanks for the suggestion.	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
52229	60	28	60	29	Extra periods on these lines.	Fixed	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
55773	60	30	60	32	Recommend deleting. There is not enough research to state with certainty that plastic pipes are compatible with hydrogen. This is an active area of research within the UK and the U.S. If blending content in the UK is desired, it would be better to replace with a few sentences on the HyDeploy project.	Actually accroding to the Iron Main Programme, this work is already in process and is not research and hence I assumed the compability of plastic pipes with hydrogen. The section is updated:"In the UK, in the Iron Mains Replacement Programme (CCC 2018), the existing low pressure gas distribution pipes are being converted from iron to plastic for health, safety, and environmental reasons. Gasunie in Netherlands has used an existing 12km natural gas pipeline for transporting hydrogen. In order to transport hydrogen in medium/high-pressure networks, reinforcements in compressor stations and pipeline construction routes (~0.13 €/kg/1000km (Wang et al. 2020)) are required (Gasunie 2019). Yet, new pipelines for hydrogen transmission at national level are likely to be required, which would require investment in the transport infrastructure."	Government of United States of America	U.S. Department of State	United States of America
55775	60	35	60	37	Are there cost estimates for pipeline conversion? Such an estimate would be useful context to understand the potential added cost of this needed conversion for existing infrastructure.	Unfortunately we did not find any specific number for this conversion.	Government of United States of America	U.S. Department of State	United States of America
71653	60	38	61	1	Paragraph describes the key challenges for hydrogen development and hydrogen economy and should be placed at the beginning of the chapter 6.4.5.1	Thanks for the suggestion, we will discuss this internally and see what is the best fit.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
78635	60	38	61	10	indeed, direct electrification is found as the least cost solution in practically all cases where appropriate, simply due to low-cost and high efficiency, while other demands requiring very high temperature or molecules-based solutions. This finding is documented in Bogdanov et al. (https://www.sciencedirect.com/science/article/pii/S0306261920316639) for a highly detailed research for the sectors power, heat, transport, industry and desalination; and also in Ram et al. (https://www.solarpowereurope.org/100-renewable-europe/)	Thanks for this. However due to space limit we are not able to expand further.	Christian Breyer	LUT University	Finland
55777	60	39	61	3	Some of these are very specific or may be confusing out of context. The item on lines 2-3 about storage sounds out of place. Recommend rewording to: "Key challenges for hydrogen are: (a) cost-effective low/zero carbon production, (b) delivery infrastructure cost, (c) land area (i.e., "footprint") requirements of hydrogen infrastructure, and (d) the cost and performance of end-uses. Advancement of a global hydrogen-based economy will require these barriers to be addressed."	The sentence has been updated: "Key challenges for hydrogen are: (a) cost-effective low/zero carbon production, (b) delivery infrastructure cost, (c) land area (i.e., "footprint") requirements of hydrogen infrastructure, (c) linepack management, (d) maintaining hydrogen purity, (e) minimizing hydrogen leakage (Office of energy efficiency and renewable energy 2018), and (f) the cost and performance of end-uses. Advancement of a global hydrogen-based economy will require these challenges to be addressed. Furthermore, it is necessary to consider the public perception and social acceptance of deployment of hydrogen technologies and infrastructure (Scott & Powells., 2020), as it could result in costly delays and enforced changes with respect to initial plans (Iribarren et al., 2016))."	Government of United States of America	U.S. Department of State	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
60141	60				The potential of HTRs for hydrogen genration is missing from Table 6.6	Taken into account. All the values are checked/updated. Due to couple of comments, table 6.6 and 6.7 are combined in order to make a proper comparison. The use of nuclear in production of hydrogen is mentioned in the text. Since, it goes through the electorlysis process, we provided a cost range for hydrogen production depending on the source.	Umasankari Kannan	Bhabha Atomic Research Centre	India
2675	61	1	61	3	This is not in my main field of expertise but I find it difficult to believe that a 12 year old study is the best available evidence to judge hydrogen cost effectiveness today!	Taken into account. For avoiding confusion we removed this sentence	Jan Wohland	ETH Zurich	Switzerland
2857	61	1	61	3	Cost effectiveness of hydrogen is not just a matter of storage. It has also to do with the economics of hydrogen production, transport and end use. Please correct this sentence.	Taken into account. For avoiding confusion we removed this sentence	Leonardo Barreto	Head of center "EU&International"	Austria
45505	61	1	61	3	Two points here: first, I think no one suggests a full global hydroge-based economy. Second, I think that even if appropriate storage is available, hydrogen would not be cost-effective compared to e.g. natural gas. Storage in salt caverns is already relatively cheap, and the main cost components for the time being are those of electricity production and electrolysis.	Taken into account. For avoiding confusion we removed this sentence	Kornelis Blok	Delft University of Technology	Netherlands
71655	61	1	61	10	Role of appropriate storage medium is not clear. Link to attractiveness of ammonia and ist benefits compared to hydrogen are not clear. Consistency to box 6.6, box 6.7 and box 6.8 should be given	Rejected. The section on hydrogen energy carriers is improved and more references are added. However, due to space limit we are not able to expand further.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
80999	61	1	61	2	It is concluded that hydrogen salt cavern storage has 'still many challenges from techno-economic perspective, due to the large size and minimum pressure requirements of the sites. As described in comment 12, hydrogen storage in salt caverns is a mature technology, several caverns in the world are already in use for hydrogen storage for many decades. In a cavern up to 240 GWh H2 (HHV) can be stored, I would say that this is an advantage. Capex cost for hydrogen storage in salt caverns is about 0.5 Euro/kWh H2 (HHV) that is very cheap compared to other storage technologies. The storage in salt caverns is between a pressure of 60-80 bar and 160-200 bar which is a proper design and already applied in many, many salt cavern natural gas storage systems. The given references do not support these conclusions.	Taken into account. The text is updaed and relevant refrences has been added:"Currently, hydrogen is stored in bulk (Andersson and Grönkvist 2019; Caglayan et al. 2020) in geologic caverns (e.g., salt caverns operate in Sweden (Elberry, A.M et al., 2021)) and hydrides (Schlapbach and Züttel 2001), however there are still many challenges, due to salt or hard rock geologies, large size, and minimum pressure requirements of the sites (IEA 2019). " However, due to space limit we are not able to expand further.	Ad van Wijk	TU Delft	Netherlands
55779	61	3	61	10	Recommend rewording this paragraph starting from "For direct large-scale hydrogen …" to "Currently, hydrogen is stored in bulk in geologic caverns. Three salt caverns operate in the U.S. and 1 in the U.K., and 1 hard rock cavern operates in Sweden, storing thousands of tonnes of hydrogen underground. This method of hydrogen storage is challenged by the requirement for salt or hard rock geologies. Other options for geographically agnostic storage include underground pipes and chemical carriers."	Taken into account. The text is updaed and relevant refrences has been added:"Currently, hydrogen is stored in bulk (Andersson and Grönkvist 2019; Caglayan et al. 2020) in geologic caverns (e.g., salt caverns operate in Sweden (Elberry, A.M et al., 2021)) and hydrides (Schlapbach and Züttel 2001), however there are still many challenges, due to salt or hard rock geologies, large size, and minimum pressure requirements of the sites (IEA 2019). " However, due to space limit we are not able to expand further.	Government of United States of America	U.S. Department of State	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
4125	61	11	63	20	This sub-section is entitled "Ammonia, ..." but the following discussions also contain other carriers like carbon-based LOHCs. Besides, the discussions on various technologies (fuel types), costs and environmental impacts are so mixed up and confusing. So, please be more specific and focused in developing the arguments on these fuels and topics one by one. Otherwise, readers may not be so sure about how much these important technologies for carbon-free energy systems can be promising towards the future. To help readers, Fig. 6.18 can be more detailed to include, say, possible environmental impacts occurring in each process, energy losses, required transport/storage infrastructure, as well as other carriers like LOHCs.	Rejected. The section from Ammonia; promosing… is improved and the title is changed to "Hydrogen Energy Carriers". Furthermore, the figure is updated siginificantly. However due to space limit we are not able to expand further.	Tatsuki Ueda	National Agriculture and Food Research Organization	Japan
17383	61	11	61	11	ecpected efficiency of hydrogen-to-amonnia should be quantified. (the same for H2->methanol)	Taken into account. Fixed:"Ammonia as another hydrogen carrier is produced from synthesizing hydrogen with nitrogen (18% energy loss (Smith et al., 2020)), and then shipped via sea in liquid form. Ammonia is a liquid fuel at temperatures of below -33ºC and is therefore more straightforward and less costly to transport than LNG or LH2 (Singh et al. 2018). There is currently energy loss of about 15-25% when cracking ammonia back into hydrogen (Bell and Torrente-Murciano 2016; Hansgen et al. 2010; Montoya et al. 2015), which could favor the use of ammonia, rather than hydrogen in certain sectors (e.g., a project where ammonia could be exported from Saudi Arabia to Japan is under consideration (Nagashima 2018)). "	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
17519	61	11	63	20	This sections presents various hydrogen carriers not only ammonia. Please consider changing the title and the structure. Thanks	Taken into account. The section from Ammonia; promosing… is improved and the title is changed to "Hydrogen Energy Carriers".	Alaa Al Khourdajie	IPCC	United Kingdom (of Great Britain and Northern Ireland)
48135	61	11	61	11	Please clarify that ammonia is a dangerous air pollutant when released to the air. It easily enters and forms particles (PM2.5). When combined with nitrate, it forms ammonium nitrate, the leading cause of visibility degradation in Los Angeles smog.	Taken into account. This sentence is updated: "Particularly, beside the GHG emissions in the life cycle assessment (LCA) of hydrogen energy carriers, a key challenge in use of ammonia is related to NOx emissions (released from nitrogen and oxygen combustion) and unburned ammonia, which have substantial air pollution risk, not only from a health perspective (e.g., ammonia gas may cause lung injury, and the liquefied gas can cause frostbite and corrosive injury to eyes and skin (EnviroMed Detection Services, 2021)), but also from visibility perspective (EPA 2001). "	Mark Jacobson	Stanford University	United States of America
7877	61	12	61	12	Ammonia does not require CO2 to be synthesised (NH4)	Taken into account. The sentence is updated to avoid confusion	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
10951	61	14	61	14	make clear "in the intensive industries"?(in the energy intensive industries?)	fixed	Dong-Woon NOH	Korea Energy Economics Institute	Republic of Korea

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
16375	61	14	61	14	make clear "in the intensive industries"?(in the energy intensive industries?)	fixed	Government of Republic of Korea	Korea Meteorological Administration (KMA)	Republic of Korea
70151	61	22			(DAC) technologies (IRENA 2019b). Although the short-term possibilities of net-negative emissions from DAC are questionable (Sekera & Lichtenberger 2020). https://link.springer.com/article/10.1007/s41247-020-00080-5	Taken into account. Thanks for this. This is added to the text.	Rayner Andersen	Department of Fisheries and Oceans	Canada
71657	61	24	61	25	Cost figures for ammonia and comparison to hydrogen should be given for status quo and for future scenarios	Rejected. The topic is interesting and important. However, space limits prevent us from addressing it here	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
2677	61	25	61	25	"… ammonia is the most cost-effective synthethic fuel": I doubt that this conclusion is true for all plausible future scenarios and use cases.	Taken into account. I updated the sentence to:"ammonia is a promising cost-effective synthetic fuel (Creutzig et al. 2019a; The royal society 2019; IEA 2019)."	Jan Wohland	ETH Zurich	Switzerland
45507	61	26	61	28	I think the term high toxicity is too strong for NOx, but clear we should not have more of it in the atmosphere. But we know how to avoid that right, with 30 years of experience of selective catalytic converters (requiring ammonia as well!).	Taken into account. I updated the sentence to be not too strong:"Transporting and storing ammonia is more cost effective than hydrogen, however direct use of ammonia for electricity generation produces substantial NOx emissions, which are toxic (Zengel et al.,2020; Lamas & Rodriguez., 2019) (high confidence). "	Kornelis Blok	Delft University of Technology	Netherlands
55781	61	26	63	20	There are many statements about NOx and toxicity of ammonia. These should be referenced.	Taken into account. The following references are added: (Zengel et al.,2020),(Lamas & Rodriguez., 2019)	Government of United States of America	U.S. Department of State	United States of America
10993	61	29	61	29	insert ")" at "Soloveichik 2016)"	fixed	Dong-Woon NOH	Korea Energy Economics Institute	Republic of Korea
16417	61	29	61	29	insert ")" at "Soloveichik 2016)"	fixed	Government of Republic of Korea	Korea Meteorological Administration (KMA)	Republic of Korea
7879	61	36	61	36	Ammonia is considered to be a scalable and cost-effective fuel source -- but at the moment not at a household level. It is more focussed as a business to business or as an industry fuel, where the safety regimes can be controlled better and therefore can be higher than in a household setting.	Taken into account. This is correct and we did not mention that it will be used for household level:"At present, major ammonia production is used in fertilizers (~80%), followed by many industrial processes such as manufacturing of mining explosives, and petrochemicals (Jiao and Xu 2018). "	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
61805	61	37	62	2	In the text, it is mentioned that "[..] ammonia can be produced from low/zero carbon generation technologies such as RES (Kraemer 2018) and nuclear (Jaszczur et al. 2016)." Yet the word nuclear is left out from the associated Figure 6.18 while renewables are mentioned explicitly. Either include both "nuclear" and "renewables" in Fig 6.18, or leave them both out.	Taken into account. The sentence has been updated: "(d) from low/zero carbon energy sources such as renewables and nuclear using high temperature reactors (Jaszczur et al. 2016) in electrolysis process (Schmidt et al. 2017a) and thermochemical water splitting (EERE 2020), "	Rauli Partanen	Think Atom	Finland
65837	61	37	62	2	In the text, it is mentioned that "[..] ammonia can be produced from low/zero carbon generation technologies such as RES (Kraemer 2018) and nuclear (Jaszczur et al. 2016)." Why is the word nuclear then left out from the associated Figure 6.18 while renewables are mentioned explicitly? Either include both "nuclear" and "renewables" in Fig 6.18, or leave them both out.	Taken into account. The sentence has been updated: "(d) from low/zero carbon energy sources such as renewables and nuclear using high temperature reactors (Jaszczur et al. 2016) in electrolysis process (Schmidt et al. 2017a) and thermochemical water splitting (EERE 2020), "	Eero Hirvijoki	Aalto University	Finland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
69615	61	39	61	39	Like that of methanol, synthetic hydrocarbons or direct-reduced iron, the production of hydrogen and ammonia based on variable renewables such as solar and wind creates specific issues (while the all-electric production of hydrogen ammomnia has been used from 1926 to today for manufacturing ammonia near hydropower facilities in Canada, Egypt, Norway, Peru, Zimbabwe, etc...). After Philibert (2017, Renewable Energy for Industry, IEA Insights Papers) showed that this does not necessarily prevent achieving cost-effective price levels thanks to the low cost of solar and wind power in some regions of the world, Armijo, J. and C. Philibert (2020, Flexible production of green hydrogen and ammonia from variable solar and wind energy: Case study of Chile and Argentina, Int. J. Hydrog. Energy, 45, 3: 1541-1558) modelled the production of hydrogen and ammonia from solar and wind power much more precisely in different places in Argentina and Chile, showing how to dimension solar and wind capacities, hydrogen buffer storage and end-plants (Haber-Bosch loops for ammonia, methanol reactors, Fischer-Tropsch plants for synthetic hydrocarbon) and run them flexibly to achieve the lowest possible cost. The IEA 2019 Future of Hydrogen illustrated the same principles with the modelling of the production of ammonia from solar and wind in China. A promising option for greater efficiency is the co-electrolysis of air and water in SOEC followed by Haber-Bosch process, with the waste heat from HB being used for the SOEC. Besides higher electrolysis efficiency, the route proposed by Haldor Topsoe would allow skipping the air separation unit of conventional all-electric hydrogen ammonia facilities.	Rejected. Thanks for this. Unfortunately due to space limit we are mpe able to expand further.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
84487	62	1	62	2	The figure may be enhanced and synthesized with similar figures in the smart energy systems literature, e.g. https://doi.org/10.1016/j.segy.2021.100007	Taken into account. This section is improved and the figure is updated	Siir KILKIS	The Scientific and Technological Research Council of Turkey	Turkey
85979	62	1	62	2	Consider using an alternate word for "gasification", e.g. "volatilisation", in Figure 6.18. The use of the word "gasification" to describe the process of converting liquid hydrogen to gas phase hydrogen could confuse readers given that the term "gasification" is also used in the chapter to describe the process of converting hydrocarbons, e.g. coal and natural gas, to H2 and CO.	Taken into account. This section is improved and the figure is updated	Government of Australia	Department of Industry, Science, Energy and Resources	Australia
51389	62	4			Ammonia can be liquefied in order	Taken into account. To avoid confusion this sentence has been updated:"Hydrogen can be liquefied (LH2) in order to be transported at volume via sea and without pressurization, while this requires temperature of –253ºC and is therefore energy-intensive, and hence increasing the cost of transport (Office of energy efficiency et al. 2018; Hydrogen Europe 2018).."	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
85783	62	8	62	8	Suggest listing the name of this demonstration project: The Hydrogen Energy Supply Chain Pilot Project.	It is added.	Government of Australia	Department of Industry, Science, Energy and Resources	Australia
85785	62	8	62	9	Suggest rewording this sentence to make it clearer that liquefied hydrogen is the mode of transport being explored in this project, the project is not exploring alternatives to liquefied hydrogen as a transport medium. (Reference: https://www.spglobal.com/platts/en/market-insights/latest-news/coal/112020-australia-japan-hydrogen-project-eyes-full-operations-by-next-decade-conference, accessed 4 February 2021).	Taken into account. Fixed: "exploring the option of exporting LH2 to Japan "	Government of Australia	Department of Industry, Science, Energy and Resources	Australia

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
51391	62	9			exporting liquefied hydrogen to Japan (Yamashita et al. 2019). Alternatively, hydrogen can be stored at 700 bar in	This is ture, but here we tried to provide a demonstration project regarding the transport of liquified hydrogen.	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
51393	62	9			lightweight carbon-fibre reinforced composite containers, and these have been used in hydrogen fuel cell powered trucks.	Noted. Thanks for this.	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
69619	62	12	62	14	However, ammonia can be used directly as a fuel, so that extraction is not always necessary (except for use in PEM fuel cells, and probably as reductant in direct iron reduction). Another possibility is that of partial extraction, with no separation of substances, to obtain a mix of ammonia and hydrogen being used as a fuel, where hydrogen plays the role of a pilot fuel, increasing the flammability of hydrogen, and avoiding the need for very high compression rate and temperature that would lead to high NOx production. See, e.g., Alfa Lava, Hafnia, Haldor Topsoe, Vestas and Simens Gamesa, 2020, Ammonfuel - an industrial view of ammonia as a marine fuel. Coupled with an efficient maritime internal combustion engine, the necessary heat for partial cracking could be produced from exhaust gases (Kim et alii.2020, A Preliminary Study on an Alternative Ship Propulsion System Fueled by Ammonia: Environmental and Economic Assessments, J. Mar. Sci. 8, 183; doi:10.3390/jmse8030183.; De Vries, N. 2019, Safe and effective application of ammonia as a marine fuel, Thesis for the degree of M.Sc. in Marine Technology, https://repository.tudelft.nl/	Rejected. As mentioned in the figure and the text as well there is couple of applications for ammonia direct use. However, due to the space limit we are not able to expand this further.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
69617	62	15	62	15	Of 14 projects currently aiming at hydrogen exports, 7 would be based on ammonia, according to BNEF.	Taken into account. The sentence is slightly updated	Cédric PHILIBERT	Institut Français des Relations Internationales	France
69621	62	17	62	24	LOHCs are the potential hydrogen carriers that request the highest energy amount for extracting the hydrogen at the end use point - more than the cracking ammonia mentioned on line 13, which is only optional. The required energy is only comparable to that of liquefaction of hydrogen, except that the energy is needed at the end point, presumably where energy is scarce and costly, and not (as is the case for hydrogen liquefaction) at the exporting point where presumably the energy is abundant and cheap. As dehydrogenation must be complete (contrary to partial cracking of ammonia to blend ammonia with some dihydrogen), requiring temperatures above 300°C and absorbing 9.5 kWh/kg H2, it is unclear is exhaust gases of combustion, if closely situated from dehydrogenation location, would be sufficient. See, e.g., Wulf E. and P. Zapp, 2018, Assessment of system variations for hydrogen transport by liquid organic hydrogen carriers, Int.J.Hydrog. Energy, 1-12	Rejected. The topic is interesting and important. However, space limits prevent us from addressing it here	Cédric PHILIBERT	Institut Français des Relations Internationales	France
17521	62	29	62	30	I might misunderstood this but: lines 29-30 state that electricity can be produced from Ammonia without any Nox emissions. Meanwhile, in page 62, line 27: it states otherwise (so is the case in page 63, line 11-12). Please clarify. Thanks	Rejected. As stated in this sentence, it "can" be produced without Nox, which means it can also produce Nox, which is aligned with the other sentence.	Alaa Al Khourdajie	IPCC	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
45919	62	31	62	39	Please assess how the combustion of ammonia results in NOx, N2O and NH3 emissions, which would question the sustainability of the approach.	Rejected. The topic is interesting and important. However, space limits prevent us from addressing it here	Government of Germany	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety International Climate Policy	Germany
45921	62	35	62	37	Ammonia is produced in great amounts by livestock farming. If there are technologies available to use ammonia captured from livestock farming, e. g. from stables, within the ammonia economy, it should me mentioned here. That might be a way to put this path into a sustainable direction. (see e.g. Sommer, S. G., Webb, J., Hutchings, N. D. (2019): New Emission Factors for Calculation of Ammonia Volatilization From European Livestock Manure Management Systems. Front. Sustain. Food Syst.,Vol.3, Article 101; https://doi.org/10.3389/fsufs.2019.00101)	Rejected. The topic is interesting and important. However, space limits prevent us from addressing it here	Government of Germany	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety International Climate Policy	Germany
69623	63	3	63	5	The values for ammonia given by Bicer and Dincer 2017 cannot be considered representative of the production process of ammonia from renewables. They simulate their (imaginary) own "electrochemical ammonia synthesis reactor" (namely "electrochemical ammonia synthesis using photoelectrochemically produced hydrogen") instead of the very proven Haber-Bosch process (including in all-electric ammonia plants since 1926 in various places). Furthermore, they run the "air separation unit" in charge of producing dinitrogen for the ammonia synthesis with grid electricity, and not from renewables. 42% of the GHG assumed emissions come from nitrogen production, 27% from the electricity production and 16.5% from the electrolysis. No sufficient information is provided in this paper to support the calculation. As note Elishav et alii 2020 about this paper, "For the N3 power generation, 93% of the GHG generated is from NH3 production and could presumably be reduced if powered only by wind". A rule-of-thumb calculation would suggest, assuming ~12 CO2-eq/kWh for wind power, efficiencies of ~55% in power to ammonia production, and ~60% for ammonia combustion in CCGT, the share of wind electricity generation in the LCA of kWh electricity from wind-based ammonia should be close to 36 gCO2eq/kWh, that is, about 10 g CO2eq/MJ - the bulk of which being from electricity production for the electrolysers, not for the air separation unit, of which electricity consumption is one order of magnitude smaller - Bicer and Dincer suggest 27% of 80g/MJ, that is, 78 g/kWh.)	Taken into account. The sentence is updated accoridng to your suggestion:"The life cycle assessment for ammonia for power generation indicates lower emissions compared to natural gas (~0.10 to 0.13 KgCO2 eq./MJelec) (Bicer and Dincer 2017; Elishav et al. 2020). "	Cédric PHILIBERT	Institut Français des Relations Internationales	France
45509	63	4	63	5	Please indicate that this is per MJ of electricity (I read it as per MJ of fuel).	fixed	Kornelis Blok	Delft University of Technology	Netherlands
45923	63	11	63	14	Please also discuss the other risks of NH3 combustion - apart from health problems and visibility - in particular eutrophication and potential emissions of the greenhouse gas N2O.	Taken into account. The following is added: "a key challenge in use of ammonia is related to NOx emissions (released from nitrogen and oxygen combustion) and unburned ammonia, which have substantial air pollution risk, not only from a health perspective (e.g., ammonia gas may cause lung injury, and the liquefied gas can cause frostbite and corrosive injury to eyes and skin (EnviroMed Detection Services, 2021)), but also from visibility perspective (EPA 2001). "	Government of Germany	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety International Climate Policy	Germany

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
325	63	12	63	12	Unburned ammonia??? I suggest to the lete "unburned"	Taken into account. this is correct due to leakage issues	Sandro Fuzzi	ISAC CNR	Italy
10995	63	14	63	14	insert "(" at perspective, EPA 2001)."	Fixed	Dong-Woon NOH	Korea Energy Economics Institute	Republic of Korea
16419	63	14	63	14	insert "(" at perspective, EPA 2001)."	Fixed	Government of Republic of Korea	Korea Meteorological Administration (KMA)	Republic of Korea
69625	63	14	15		There is considerable volume of experimentation and literature relative to the ways and means to address the Nox emissions of ammonia combustion, including two-stage (lean-rich) combustors, swirl mechanisms, and selective catalytic recirculation. See e.g. Valera-Medina A. et alii, 2018, Ammonia for power, Progress in Energy Combust. Sci. 69: 63-102; Kobayashi H. et alii, 2018; Science and technology of ammonia combustion, Proc. Combust. Instit; 37: 109-133; Elishav O. et alii, 2020, Progress and Prospective of Nitrogen-Based Alternative Fuels, Chem. Rev. 120: 5352-5436 for an extensive review	Taken into account. The following is added: To deal with NOx emissions, many applications have been undertaken by selective catalytic/non-catalyst reduction, two-stage combustors, and swirl mechanisms (Lamas Galdo 2020; Valera-Medina et al. 2018). "	Cédric PHILIBERT	Institut Français des Relations Internationales	France
69627	63	16			Hydrogen possesses the NFPA 704's highest rating of 4 on the flammability scale because it is flammable when mixed even in small amounts with ordinary air; ignition can occur at a volumetric ratio of hydrogen to air as low as 4% due to the oxygen in the air and the simplicity and chemical properties of the reaction.	This is compared to natural gas, which hydrogen has lower flammability.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
45513	63	19	63	19	Maybe more precise to say that now already several of Siemens' gas turbines run on 100% H2. Note that on page 90 (lines 32 - 34) also GE is discussed.	We checked again. Although some of the turbines have the capability but so far none of them are operating fully on hydrogen.	Kornelis Blok	Delft University of Technology	Netherlands
45511	63	20	63	20	Simens should be: Siemens	Fixed	Kornelis Blok	Delft University of Technology	Netherlands
5371	63	21	65	30	The title of the chapter is "Electricity transmission". As a matter of fact, the whole chapter is mostly dedicated to tranport of electricity produced by renewable. The need for transportation network, interconnections, .. Is the same whatever the production plant is therma, or renewable. The importance of a robust grid is enhanced by the need to transport electricity in order to face variability of wind and solar prduction. (it's not the case with hydro). So, either you change the title, or you adapt the wording.	Thanks for this. In here we tried to investigate the low/zero carbon future, which the challenege is mostly on renewbales. The following is also added to show the role of HVDCs in global interconnection: "In addition to enabling integration of large share of renewables, HVDC interconnections could enhance resilience of electricity supply, acting as a 'firewall' through blocking the spread of disturbances while permitting the interchange of power (US Energy Information Administration, 2018; Roberson et al, 2019). "	Michel SIMON	Retraité/ Pdt d'association	France
9529	63	21	63	21	I did not see any references to public perceptions or community acceptance research on high voltage transmission power lines, which is a gap since there have been many objections to projects in countries like the US, UK and Ireland from people around many impact issues including health, property values, landscape values, place attachments (e.g. DOI: 10.1177/0013916512440435; https://doi.org/10.1016/j.erss.20; http://dx.doi.org/10.1016/j.enpol.2017.04.008) and high voltage power lines will be critical to handline variable power generation in countries with large centralised grid networks.	Taken into account. The following is added: "However, at the same time, a broad range of geopolitical and socio-techno-economic challenges will need to be overcome to support this level of international co-operation, as well as large-scale network expansion (MARSH JLT.,2020)." However due to space limit we are not able to expand further.	Patrick Devine-Wright	University of Exeter	United Kingdom (of Great Britain and Northern Ireland)
17385	63	21	63	21	Chapter Electricity Transmission. Insufficient emphasis on strongly increased transmission capabilities in case of very high wind and solar penetration. Problematic social acceptability of the new transmission lines. No comments on the security of electricity supply in case of very high wind and solar penetration (California heat wave in Fall 2020, Texas winter storm 2020/21)	Taken into account. The following is added:"In addition to enabling integration of large share of renewables, HVDC interconnections could enhance resilience of electricity supply, acting as a 'firewall' through blocking the spread of disturbances while permitting the interchange of power (US Energy Information Administration, 2018; Roberson et al, 2019)"	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
61807	63	21	65	30	The entire section 6.4.5.2 "Electricity Transmission" is written from the perspective of having to integrate a dominant share of non-dispatchable renewables, yet this is not the only (nor is it proven) way to decarbonize the electricity grid, as France has shown. Therefore, the section should also include a statement that focusing on nuclear would avoid many of the issues that a grid with a high share of variable solar and wind production will have, and that it should be taken into account when national plans are made, as extensive transmission expansions have proven to be problematic, slow and expensive (e.g. Germany)	Out of scope. Detailed investigation on nuclear is provided in section 6.4.3. Due to space limit, we are not able to expand the issue here as well. The following sentence is updated:") and (iii) more cost-effective deployment of renewables and other low carbon sources (e.g., nuclear and hydro) "	Rauli Partanen	Think Atom	Finland
64413	63	21	65	30	The section on transmission does not adequately address siting, permitting, real estate, cost sharing, and political challenges with developing and constructing high voltage transmission infrastructure, particularly at seams between regions. The timeline for developing a new high voltage line or ultra-high voltage line is often greater than ten years and can be fifteen years or longer depending on jurisdiction. This timeline is in direct conflict with the speed at which new renewable energy must be brought online to meeting goals and commitments. The authors did not address any of the complex issues associated with property rights, environmental impacts, or local, regional, and national politics. When it comes to grid design and integration of renewables, I do not believe the technical challenges are critical path, so suggest this section be restructured to focus on the primary challenges (e.g., political, property rights, permitting, cost allocation, etc.), recognizing that grid upgrades will be required in all pathways involving high renewable energy integration and that those upgrades will need to occur on an accelerated timeline. As noted elsewhere in this chapter grid enhancement is a significant percentage of the investment (>30%) required for deep decarbonization and should be more thoroughly addressed in this chapter.	Taken into account. The following is added: "However, at the same time, a broad range of geopolitical and socio-techno-economic challenges will need to be overcome to support this level of international co-operation, as well as large-scale network expansion (MARSH JLT.,2020)." However due to space limit we are not able to expand further.	Curt Bjurlin	Stantec Consulting	United States of America
65839	63	21	65	30	The entire section 6.4.5.2 "Electricity Transmission" is now crafted from the perspective of having to integrate a dominant share of non-dipatchable renewables. The section should also include a statement that focusing on nuclear would avert majority of the grid related issues and costs of scenarios with high-shares of variable solar and wind production. Revise accordingly.	Out of scope. Detailed investigation on nuclear is provided in section 6.4.3. Due to space limit, we are not able to expand the issue here as well. The following sentence is updated:") and (iii) more cost-effective deployment of renewables and other low carbon sources (e.g., nuclear and hydro) "	Eero Hirvijoki	Aalto University	Finland
74205	63	21	65	13	This section only talks about the need to have better transmission for renewables. It should modifed to discuss the benefits of better transmission interconnections to help transmit carbon free generation, including nuclear and hydro among others.	Taken into account. The following sentence is updated:") and (iii) more cost-effective deployment of renewables and other low carbon sources (e.g., nuclear and hydro) ". At the beginning of the section, nuclear and hydro are added, but since one of the key elements in decarbonisation of the future is large penetration of renewables, our focus is mostly on renewables. As an example, the idea is to install solar in Greece, and wind in Scotland to get the most benefits and educe the curtailments, however nuclear can be built everywhere.	Jeffrey Merrifield	Pillsbury Law Firm	United States of America
71659	63	22	63	24	Statement should be supported by cost figures and studies, examples for cost efficiency esp. compared to other technologies like storage could be given.	Rejected. The topic is interesting and important. However, space limits prevent us from addressing it here	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
75751	63	22	65	30	The section does not reflect on research indicating that widespread distribution of renewable energy sources, in particular wind turbines, does not guarantee increase in annual minimum power output. For example in 2016 28000 wind turbines in Germany had a minimum of 1% nominal power output, and for 18 Europe countries it was around 5%, indicating the necesity for backup power regardless of good conectivity (Linnemann, Thomas, & Vallana, Guido S. (2017). Wind energy in Germany and Europe Status, potentials and challenges for baseload application Pt 1 Developments in Germany since 2010. Atw Internationale Zeitschrift fuer Kernenergie, 62(11), 678-688.) and also Part 2	Taken into account. Correct! The folliwing is added:"In addition to enabling integration of large share of renewables, HVDC interconnections could enhance resilience of electricity supply, acting as a 'firewall' through blocking the spread of disturbances while permitting the interchange of power (US Energy Information Administration, 2018; Roberson et al, 2019). " beside in section 6.4.3 we presented the role of hydrogen storage in extreme weather conditions to increase the resilience:"Hydrogen could also provide long-term storage in order to deal with extreme events, such as low output of renewable generation for long durations or a significant increase in demand driven by extreme weather conditions."	Krešimir Trontl	University of Zagreb, Faculty of Electrical Engineering and Computing	Croatia
37717	63	23	63	23	There is a cost attached to developing a long length transmission infrastructure. Please highlight the cost aspect. Also compare the additional cost with the cost of setting up nuclear power plants, which are being described as capital intensive.	Reejcted out of scope. Regarding Nuclear, a comprehensive part is presented in system integration section. Regarding cost, it is mentioned in the last paragraph:"Market design, regulation and policy framework related to the development of regional interconnections should be aligned with the decarbonization agenda in order to support cost-effective deployment of renewable generation, which remains one of the main drivers of power system reform and redesign (ENTSO-E 2020b) ". Which the investment part is reflecting this.	Ravi B Grover	Homi Bhabha National Institute	India
2679	63	33	63	36	I don't think that this example applies everywhere. It is correct for Europe and probably other locations in the mid-latitudes but not globally.	Correct, it may not applicable in all areas (could be North to south of US, or China, etc.), but we could say it is global perspective.	Jan Wohland	ETH Zurich	Switzerland
71661	63	33	63	36	Example is given for the European Power System? Regional scope is not clear or should be explained	The topic is interesting and important. However, space limits prevent us from addressing it here and we only provided the example for EU.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
69629	63	34			A wording for both hemisphere would be "facilitate the polward to equatorial flows" - the way North and South are used here is only valid in the Northern hemisphere.	Fixed.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
2861	63	36	63	39	A regional approach towards the deployment of renewables is feasible in regions that are politically and economically strongly integrated and that have adequate regional energy governance mechanisms in place that can steer a coordinated deployment. A global approach, however, would be much more challenging and requires international coordination, technology transfer and market incentives that enable the cost effective deplyoment of renewables in those regions where the potentials are higher.	Taken into account. The following is added: "However, at the same time, a broad range of geopolitical and socio-techno-economic challenges will need to be overcome to support this level of international co-operation, as well as large-scale network expansion (MARSH JLT.,2020)." However due to space limit we are not able to expand further.	Leonardo Barreto	Head of center "EU&International"	Austria
18245	63	39	63	46	(Section 6.4.5.2) It would be useful to briefly mention any trade-offs (or positive reinforcements) of fully coordinated deployment across large geographic regions in terms of environmental impacts. For example, are impacts lower because less supply plant is required? Or higher because more transmission infrastructure needs to be built?	Rejected. Thanks for this. These issues are widely discussed in the section. Unfortunately, due to space limit, we cannot make another statement about this	Government of United Kingdom (of Great Britain and Northern Ireland)	Department for Business, Energy & Industrial Strategy	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
2859	63	40	63	46	Full coordinated deployment of renewables requires European-wide coordination and governance mechanisms that allow the deployment of renewables in those areas of the continent where potentials are larger and it is more cost effective (e.g. solar in southern Europe). The EU is implementingn an EU-wide renewable financing mechanism that provides incentives for Member States to work together towards the achievement of the EU collective RES target and facilitate a more cost-effective roll-out of renewables across the EU (https://ec.europa.eu/energy/topics/renewable-energy/eu-renewable-energy-financing-mechanism_en)	Taken into account. A generic statement is added in the text:"However, at the same time, a broad range of geopolitical and socio-techno-economic challenges will need to be overcome to support this level of international co-operation, as well as large-scale network expansion (MARSH JLT.,2020)." However due to space limit we are not able to expand further.	Leonardo Barreto	Head of center "EU&International"	Austria
84355	63	43	63	43	see also: R. Cluet, N. Maïzi, and V. Mazauric, "From centralized to decentralized power system: A space-analysis for France," International Journal of Applied Electromagnetics and Mechanics, vol. 64, pp. 73–78, 2020.	Taken into account. Reference is added	Vincent MAZAURIC	Schneider Electric	France
51395	63	44			more wind in areas with high wind potential and more solar in areas with better solar irradiance, connectivity and	Fixed	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
7881	63	46	63	46	There are geopolitical risks of networks across greater political boundaries. This has a security of supply implication - and needs careful consideration against the technical benefits of long-distance networks -- (a similar point is mentioned on page 97 line 46 : At the same time, a broad range of geopolitical and socioeconomic challenges will need to be overcome to support this level of international co-operation, as well as the techno-economic challenges associated with large-scale network expansion.	Taken into account. A generic statement is added in the text:"However, at the same time, a broad range of geopolitical and socio-techno-economic challenges will need to be overcome to support this level of international co-operation, as well as large-scale network expansion (MARSH JLT.,2020)." However due to space limit we are not able to expand further.	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
84353	64	5	64	5	see also Ringo project by the French TSO (RTE): https://youtu.be/Nx93NxPgn4I	its language is not English	Vincent MAZAURIC	Schneider Electric	France
2681	64	9	64	12	I am not convinced by this claim. Why should global cooperation require a globally interconnected system? Studies have repeatedly demonstrated that decarbonization is possible on smaller spatial scales than globally (continental, national or decentral systems are often possible).	Yes this is correct, we need to find the balance between local and global interconnection for cost effectiveness perspectives.	Jan Wohland	ETH Zurich	Switzerland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
4569	64	9	64	12	The text mentions the concept of global grid interconnection corresponding to climate change, but it does not explain it much. In fact, some institutes have already carried out research on global grid interconnection planning to consider climate change. It is recommended that the latest research progress and results be included in the report for supporting explanation. Suggestion: “Global co-operation in improving reliability of electricity systems and ability to mitigate the consequences of global warming will require a globally interconnected system that would improve both economic performance and reliability (Breyer et al. 2019; Bogdanov et al. 2016)” is modified as “Global co-operation in improving reliability of electricity systems and ability to mitigate the consequences of global warming will require a globally interconnected system that would improve both economic performance and reliability (Breyer et al. 2019; Bogdanov et al. 2016)。GEIDCO evaluates the influence of global energy interconnection on climate change mitigation, and total intercontinental power flow is expected to reach to 800 GW by 2050 in 1.5℃ scenario by taking advantages of diurnal, seasonal, and resource differences of different renewable energy across all continents” (GEIDCO, IIASA, WMO, 2019). Reference: GEIDCO, IIASA, WMO, 2019: Research Report on Global Energy Interconnection for Addressing Climate Change. Beijing: China Electric Power Press	Taken into account. Thanks for this. The sentence has been updated:"This marks the UHVDC transmission project with the highest voltage level, the largest transmission capacity, the longest transmission distance, and the most advanced technology in the world (Liu 2015a), that is a key technology for the development of global and trans-continental interconnected mega-grids, which is a major for achieving global energy interconnection (Liu 2015b; GEIDCO, IIASA, and WMO 2019). "	Shining Zhang	GEIDCO	China
37719	64	12	64	12	Please inform the reader how expensive these developments are to make them realise that only developing countries can afford such CAPEX.	Taken into account. The topic is interesting and important and we updated our section. However, space limits prevent us from addressing it here. However it is mentioned in the last paragraph:"In this context, market design, investment, infrastructure regulation and policy framework related to the development of regional interconnections should be aligned with decarbonization agenda, which remains ". Which the investment part is reflecting this.	Ravi B Grover	Homi Bhabha National Institute	India
71663	64	12	64	14	Negative impacts of globally interconnected systems could be explained in more detail	Taken into account. A generic statement is added in the text:"However, at the same time, a broad range of geopolitical and socio-techno-economic challenges will need to be overcome to support this level of international co-operation, as well as large-scale network expansion (MARSH JLT.,2020)." However due to space limit we are not able to expand further.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
70165	64	14			Capellán-Pérez et al. 2017). These concerns include major discrepancies between known mineral reserves and required amounts of minerals for even a 75% conversion to global renewable use. Minerals such as Tellerium, Indium, Tin, Silver, and Gallium show major discrepancies between quantitative requirements under green growth scenarios and known reserves (Capellán-Pérez et al, 2019). https://www.sciencedirect.com/science/article/pii/S2211467X19300926?	Rejected. The topic is interesting and important. However, space limits prevent us from addressing it here	Rayner Andersen	Department of Fisheries and Oceans	Canada

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
55783	64	23	64	26	What are "wet devices"?	Taken into account. updated:"Increased interconnectivity of large-scale grids also allows the aggregation of 'smart grid' solutions such as flexible demand (e.g. from wet devices, such as washing machines (Labeeuw et al. 2015)) or use of EVs (Rassaei et al. 2015) to improve regional system performance. "	Government of United States of America	U.S. Department of State	United States of America
51397	64	25			flexible demand from wet devices, such as washing machines (Labeeuw et al. 2015)	Taken into account. updated:"Increased interconnectivity of large-scale grids also allows the aggregation of 'smart grid' solutions such as flexible demand (e.g. from wet devices, such as washing machines (Labeeuw et al. 2015)) or use of EVs (Rassaei et al. 2015) to improve regional system performance. "	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
28955	64	27	64	27	I suggest to add the first study on the feasibility of a global electricity grid: The study of (REFERENCE) investigated on how a globally interconnected grid could provide cost-effective, low-carbon power system spanning all continents. REFERENCE: Yu et al. (2019): Global electricity network Feasibility study	Taken into account. The text has been added:"Advantages of globally interconnected grid providing cost-effective, low-carbon power systems spanning all continents have been investigated (Yu et al, 2019). "	Fabian Heymann	INESC TEC	Switzerland
80481	64	27	64	27	It would be good to expand this paragraph with something along the following lines. "Similar proposals exist for an Australia-Asian power grid with huge benefits for the region (https://dx.doi.org/10.3390/en11010200). A ~USD 17 billion project development agreement for an Australia-ASEAN Power Link (AAPL) was signed in January 2021 for connecting a 10GW of photovoltaics in the north of Australia via a 4,500km 3GW HVDC cable to Singapore and a 10GWh battery there, suggesting that this makes economic sense (https://suncable.sg/australia-asean-power-link/)."	Taken into account. This section is improved/updated:"Similar proposals exist for an Australia-Asian power grid, delivering major benefits for the region (Halava et al. 2018). A ~USD 17bn project development agreement was signed in January 2021 for connecting a 10GW of PVs in the north of Australia via a 4,500km 3GW HVDC cable to Singapore and including 10GWh battery, suggesting that this would be cost effective (Sun Cable, 2021)."	Moritz Riede	University of Oxford	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
15253	64	28	64	31	The statement here does not match the facts and the usage of key terms is inaccurate. 1. The original sentence reads "The State Grid Corporation of China is building a 1.1 million Volt transmission line", which is inconsistent with the actual situation. The China Changji-Guzhuan ±1100 kV UHV DC transmission project was put into operation in September 2019. 2. It is suggested to express the "1.1 million kV" UHV voltage level in the universal unit of ±1100 kV. Specific modifications: Change “The State Grid Corporation of China is building a 1.1 million Volt transmission line (12 GW voltage source converter transmission technologies: the right fit for the application capacity) that will be able to transport electricity over 2,000 miles (Fairley 2016). This project is the first of its kind in the world, and a major step towards the development of international and intercontinental mega-grids.” to “In September 2019, the Changji-Guquan ±1,100 kV ultra-high-voltage direct current (UHV DC) transmission project built by State Grid Corporation of China was officially completed and put into operation. The transmission line traverses for a total distance of 3,341km and is capable of transmitting up to 12GW of rated power (Pei et al. 2020). This marks the UHV DC transmission project with the highest voltage level, the largest transmission capacity, the longest transmission distance, and the most advanced technology in the world (Liu 2015a), and is a necessary technology for the development of global and trans-continental interconnected mega-grids, which is a major step to achieve global energy interconnection (Liu 2015b; GEIDCO, IIASA, and WMO 2019).” The supporting literature is as follows: Liu.Z., 2015a: Ultra-High Voltage AC/DC Grids. Massachusetts: Academic Press. Liu.Z., 2015b: Global Energy Interconnection. Massachusetts: Academic Press. Pei, Y., Niu L., Liu J., Gao N., Wang L., Li P., Yin Q., and Wang L., 2020: Research on the Training Program and Develop the Curriculum System for HVDC Equipment	Taken into account. Thanks for this. This section is updated accordingly.	Government of China	China Meteorological Administration	China

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
28533	64	28	64	46	The section on HVDC lines clearly needs an update, see for reference https://www.power-technology.com/features/featurethe-worlds-longest-power-transmission-lines-4167964/	Taken into account. The topic is interesting and important and we updated our section. However, space limits prevent us from addressing it here. However we updated this part by providing new references: "Similar proposals exist for an Australia-Asian power grid with huge benefits for the region (https://dx.doi.org/10.3390/en11010200). A ~USD 17 billion project development agreement for an Australia-ASEAN Power Link (AAPL) was signed in January 2021 for connecting a 10GW of photovoltaics in the north of Australia via a 4,500km 3GW HVDC cable to Singapore and a 10GWh battery there, suggesting that this makes economic sense (https://suncable.sg/australia-asean-power-link/). In September 2019, the Changji-Guquan ±1,100 kV ultra-high-voltage direct current (UHV DC) transmission project built by State Grid Corporation of China was officially completed and put into operation. The transmission line traverses for a total distance of 3,341km and is capable of transmitting up to 12GW of rated power (Pei et al. 2020). This marks the UHV DC transmission project with the highest voltage level, the largest transmission capacity, the longest transmission distance, and the most advanced technology in the world (Liu 2015a), and is a necessary technology for the development of global and trans-continental interconnected mega-grids, which is a major step to achieve global energy interconnection (Liu 2015b; GEIDCO, IIASA, and WMO 2019)"	Pierpaolo Cazzola	International Transport Forum	France
69631	64	28	64	46	One may also note that HVDC is often used for submarine connections. In the last decades submarine lines have significantly increased in number, notably from Norway to Poland, Germany, Denmark, the Netherlands, etc. The link between France and the UK has been doubled. HVDC links have been established between France and Spain after decades of infructuous attempts to deploy HVAC lines facing public opposition. Aerial HVDC lines have much smaller footprint than aerial HVAC lines. HVDC lines are much better adapted for underground cables. HVDC lines do not request synchronisation of frequency between the power systems they link, which is sometimes an advantage (allowing to link non synchronised systems) and somestimes an inconvenient (not helping maintaining frequency control).	Rejected. The topic is interesting and important and we updated our section. However, space limits prevent us from addressing it here	Cédric PHILIBERT	Institut Français des Relations Internationales	France
2683	64	29			“ the right fit for the application capacity” sounds like an advertisement	fixed	Jan Wohland	ETH Zurich	Switzerland
2863	64	29	64	31	The deployment of international or interconntinental electricity grids depends, among others, on political conditions. Regions with political instability may difficult the deplyoment of intercontinental grids.	Correct! The sentence is updated.	Leonardo Barreto	Head of center "EU&International"	Austria
52231	64	29	64	29	"the right fit for the application capacity" is too editorial and should be removed.	Removed.	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
18247	64	31	64	32	(Section 6.4.5.2) HVAC = high voltage alternating current (not alternative current as currently written).	Fixed	Government of United Kingdom (of Great Britain and Northern Ireland)	Department for Business, Energy & Industrial Strategy	United Kingdom (of Great Britain and Northern Ireland)
80483	64	31	64	31	Maybe start a new paragraph after “mega-grids.” The text before is a country specific example and could be merged with the previous paragraph (64-15 to 64-27). The text afterwards is about various transmission technologies that are country-independent.	fixed	Moritz Riede	University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
18249	64	47	65	12	(Section 6.4.5.2) This section would benefit from a discussion of the geopolitical implications / risks associated with cross-border grids. For example, the increased risk that one nation could control another by threatening access to power; the increased range of hybrid threats that would be associated with transnational grids (eg to ICT support networks); etc.	Taken into account. A generic statement is added in the text:"However, at the same time, a broad range of geopolitical and socio-techno-economic challenges will need to be overcome to support this level of international co-operation, as well as large-scale network expansion (MARSH JLT.,2020)." However due to space limit we are not able to expand further.	Government of United Kingdom (of Great Britain and Northern Ireland)	Department for Business, Energy & Industrial Strategy	United Kingdom (of Great Britain and Northern Ireland)
73975	64	47	65	1	This statement is vague. Of course markets and regulation should be aligned with decarbonization agenda. The question is how should they change to be aligned?. If there are no clear directions here, it is better to just not make these statements.	Taken into account. The follwing is updated:"Market design, investment, regulation and policy framework related to the development of regional interconnections should be aligned with the decarbonization agenda in order to support cost-effective deployment of renewable generation, which remains one of the main drivers of power system reform and redesign (ENTSO-E 2020b)"	Heleno Miguel	Lawrence Berkeley National Laboratory	United States of America
2865	65	13	65	16	Opportunties could arise for offshore interconnected transmission systems that combine electricity and hydrogen production in so-called energy islands (e.g. the energy island currently under planning in Denmark)	Taken into account. Correct. The following is added:"In this regard, as an example, studies such as (Konstantelos et al. 2017; Koivisto et al. 2019; Energinet 2020) investigate the potential benefits of offshore grid including wind farms and interconnectors, which is very relevant given the ambition to connect between 350GW and 490GW of offshore wind in the North Sea (E3G 2021). This analysis also considered production of hydrogen at offshore wind sites and transporting hydrogen rather than electricity, highlighting the importance of identifying appropriate balance in transport of hydrogen and electricity. "	Leonardo Barreto	Head of center "EU&International"	Austria
37721	65	27	65	30	Market design, infrastructure regulation and policy framework are not the only issues. For developing countries the main issue is CAPEX. Please highlight CAPEX as well.	Taken into account. The follwing is updated:"Market design, investment, regulation and policy framework related to the development of regional interconnections should be aligned with the decarbonization agenda in order to support cost-effective deployment of renewable generation, which remains one of the main drivers of power system reform and redesign (ENTSO-E 2020b)"	Ravi B Grover	Homi Bhabha National Institute	India
52233	65	27	65	30	Not clear what is meant by "should be aligned".	Depending on the country, different targets (decarbonisng agenda) has been set and it should be considered in developments in this area.	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
2685	65	31	67	33	This section is not particularly well aligned with the section before and after it. Maybe there could be a smoother transition from the technology-focused aspects to the behaviour-focused one and back to more technology focused aspect in the following section?	It is indeed different, maybe explain rationale better. I have to think about this	Jan Wohland	ETH Zurich	Switzerland
9531	65	31	65	31	This section is very comprehensive in its focus on consumers - it could be better connected to section 5.4 of chapter 5, which focuses on behaviour but also other factors explaining shifts in demand. This point also applies to section 6.6.3 on page 94 and to section 6.7.3.1 on page 112. Better coordination across Chapters 5 and 6 around these sections would be useful. I can help to address this.	accepted, coordination between chapters has taken place, and cross referneces were made	Patrick Devine-Wright	University of Exeter	United Kingdom (of Great Britain and Northern Ireland)
21037	65	31	65	31	This section should include something about electricity pricing to final consumers, i.e. how price schedules can help to the demand side mitigation problem (dynamic pricing, time-of-Use, Critcal Peak Pricing), how consumers react to real-time electricity price variation, how the digital tools can help to potize energy use together with the price signal	Noted. Policy instruments are discussed in section 6.7.6.1	Government of France	Ministère de la Transition écologique et solidaire	France
37723	65	31	65	31	Demand side mitigation measures are likely to hurt vulnerable sections of the society. Please explaing how that will be addressed.	Noted. Fairness and equity issues are addressed in section 6.7.6.2	Ravi B Grover	Homi Bhabha National Institute	India
55785	65	31	67	39	Here or in Section 6.4.7, it would be useful if the authors compared mitigation options across the Global North and Global South countries to indicate which options may be cost-prohibitive in the Global South. Given burgeoning energy demand and new infrastructure investments, it would be useful to differentiate between mitigation options that would be more applicable to the Global South.	Noted. Given the word limit, we cannot expand on this in this section. This issues is discussed in depth in Chapter 5	Government of United States of America	U.S. Department of State	United States of America
65843	65	31	67	32	The section 6.4.6. on "Demand side mitigation options from and energy systems perspective" devotes majority of the discussion on enabling individual choices for people. I find this emphasis on individual level weird and misplaced for the purpose of the IPCC is to enable a change at the level of intergovernmental politics that would be sufficient in mitigating climate change. I recommend more discussion of the demand side options at the system level instead of the individual person level.	Noted. Policies to mitigate demand are discussed in section 6.7.6.1 - this section indicates which factors affect energy demand that can be targeted by policy	Eero Hirvijoki	Aalto University	Finland
71665	65	31	65	31	General introduction would be helpful, see also Box 6.6: Many low-emitting and high-renewables systems also utilise increased load flexibility in the forms of energy efficiency, demand response, demand flexibility, and sector coupling (Imelda et al. 2018; Hale 2017; Merrick et al. 2018; Brown et al. 2018; Ma et al. 2013).	Noted. Indeed, this is addressed in the second bullet on p 65	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
17523	65	32	65	39	no full stops between sentences	editiorial-noted	Alaa Al Khourdajie	IPCC	United Kingdom (of Great Britain and Northern Ireland)
43591	65	32	65	39	Please fix punctuation in this paragraph	editiorial-noted	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy
55787	65	32	65	39	There are no periods in this paragraph, which makes it difficult to understand the thought contained within each sentence. There are capital letters that appear to denote new sentences, but the sentence on lines 34-37 does not make sense.	editiorial-noted	Government of United States of America	U.S. Department of State	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
73977	65	32	65	32	period (stop) missing at the end of the sentence	editiorial-noted	Heleno Miguel	Lawrence Berkeley National Laboratory	United States of America
82307	65	32	67	32	Section 6.4.6 From an energy system perspective, I would expect to read about measures that can be done in the demand sectors (and not by the actors in the demand) My confusion could be due to the fact that demand sectors are part of the energy system in my research field (comprehensive energy system analysis and modeling). In these case, wind parks and nuclear power plants are not examples on measures for mitigation on the demand side (CCS can still be a measure on industrial processes). It seem like you in this section have described what the individuals can do, individuals as persons as well as companies. This is important as well. But in my head this is not “demand side mitigations options from an energy system perspective.	Noted. Policy measures are discussed in section 6.7.6.1. We clarified that we focus on end users indeed, which includes acceptance and adoption of supply side solutions	Anna Krook-Riekkola	Luleå University of Technology	Sweden
82309	65	32	65	39	This section is very confusing. Full stop is missing on several places. (se also comment above on section 6.4.6	editiorial-noted	Anna Krook-Riekkola	Luleå University of Technology	Sweden
2867	65	35	65	37	The sentence s not clear "Moreover, end users, including 35 consumers, governments, businesses and industry, would need to adopt the relevant energy supply 36 options, and then use these in the intended way user adoption can be a key driver to scale up markets 37 for low carbon technologies"	editiorial, examples of relevant actions are included in the next paragraph	Leonardo Barreto	Head of center "EU&International"	Austria
52235	65	36	65	36	"then use these in the intended way user adoption can be a key" is not clear.	Editorial. We clarified this	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
73979	65	37	65	37	period (stop) missing at the end of the sentence	editiorial-noted	Heleno Miguel	Lawrence Berkeley National Laboratory	United States of America
33057	65	40	66	13	peer-to-peer energy trading and sharing: innovative energy trading platform that creates ‘virtual pools’ of connected energy systems within a neighbourhood. The platform can boost collaboration between users, helping them to make the most of their distributed energy storage systems. The concept of trading power is simple: renewable electricity from distributed power generators (such as rooftop photovoltaic panels or domestic wind turbines), backup batteries and a digital network combine to make peer-to-peer energy trading possible [https://cordis.europa.eu/article/id/418029-new-platform-facilitates-peer-to-peer-energy-trading-and-sharing].	Noted. This is an example of adoption of technoloigis that support flexibility in energy use, the second bullet	Yashar Hajimolana	University of Twente	Netherlands
33061	65	40	66	13	Local community energy initiatives have a huge potential to foster the energy transition and contribute to a decentralized sustainable energy system.	Noter, this is discussed in section 6.7.6.1, where we discuss strategies to promote low carbon actions	Yashar Hajimolana	University of Twente	Netherlands
47949	65	40	66	13	This list is really insightful, should it be complemented by 2-3 refs for each bullet?	Accepted, we added references above the bullets	Matteo Muratori	NREL	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
5373	65	41	65	45	Once more, the author is promoting renewable (PV and Wind) instead of "low carbon enrgies". It's a wrong recommendation to install PV or Wid farm when electricity is already carbon free, like in Iceland or France. This recommendation is going against the CO2 emissions reduction. Is that the rôle of IPCC?	Noted, please note that these are examples of the overarching category that is prhased as the use of energy sources and carriers with low carbon emissions, as this reviewer suggests. The supply of low carbon energy is discussed in the previous sections, including hydro	Michel SIMON	Retraité/ Pdt d'association	France
61809	65	41	65	43	If an option to "buy shares in a renewable energy project (e.g., wind shares), or [to] select a renewable energy provider" is promoted as an end-user measure to reduce carbon emissions, then an equivalent mention of nuclear energy must be included as well. For example in Finland, the Olkiluoto 1, 2, and 3 nuclear units are built and operated with a “co-operative”, non-profit Mankala-model, and have more than 20 industry companies and even more local electricity utilities as owners (end users) and electricity is sold at cost for the owners.	Noted, please note that this is only an example, given space limits, we decided to add a common example	Rauli Partanen	Think Atom	Finland
65841	65	41	65	43	If an option to "buy shares in a renewable energy project (e.g., wind shares), or [to] select a renewable energy provider" is promoted as an end-user measure to reduce carbon emissions, then an equivalent mention of nuclear energy must be included as well. For example in Finland, the Olkiluoto 1, 2, and 3 nuclear units are co-owned by more than 20 industry companies (end users) and electricity is available at cost price for the owners.	Noted, please note that this is only an example, given space limits, we decided to add a common example	Eero Hirvijoki	Aalto University	Finland
71667	65	41	65	43	Demand side options should be prioritized: increase of energy efficiency considering environmental costs for energy supply, electrification of heat demand and mobility combined with the usage of carbon free energy carriers (sector coupling), usage and increase of demand side flexibility for optimization of system operation and infrastructure needs	Noted, these are indeed the demand side options we discuss. We refrain from normative statements on which options would need to be prioritised, in line with the mandate of the IPCC	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
7883	65	42	65	42	suggest to buy shares in a 'new' renewable energy project	Rejected, as this would imply we would not consider buying shares in existing projects	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
73981	65	42	65	43	buying shares in a renewable energy project is a pure financial operation without any direct impact on emissions. This does not have the same effect as direct tangible purchases of behind the meter assets (such as rooftop PV)	Rejected, as this would imply we do not consider buying shares in planned projects	Heleno Miguel	Lawrence Berkeley National Laboratory	United States of America
61811	65	43	65	43	Replace “... select a renewable energy provider” with “... select a low-carbon energy provider” to be more accurate and technology neutral as well as consistent with climate mitigation efforts.	Accepted, changed accordingly	Rauli Partanen	Think Atom	Finland
47947	66	1	66	1	Electric vehicles have been show to be the largest source of demand-side flexibility, maybe some quantification here or context for the role of different end uses might be helpful (Fig 19 https://www.nrel.gov/docs/fy20osti/73336.pdf)	Noted, we unfortunately do not have the space to elaborate on this in this section, and this would fit better in the section on storage	Matteo Muratori	NREL	United States of America
74865	66	1	66	13	As a proposed measure for load shifting, Electic vehicles can be deployed to use excess eenrgy available during off peak hours and possibly reduce on Geothermal curtailment for instance	noted, this is indicated the scond bullet (top of p 66)	Government of Kenya	Kenya Meteorological Service	Kenya
71669	66	3	66	5	Energy efficiency is relavant for all energy consuming sectors (e.g. also industry or service sector). Furthermore efficiency for new appliances due to digitalization should be included/mentioned (e.g. data centers, Internet of things, blockchain applications)	Noted, we included some examples of energy efficiency, and did not aim to be complete given space limitation. Please note that energy efficiency is discussed in many of the other sectoral chapters as well	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
71671	66	6	66	8	Sufficiency and demand response should be separat points, examples for system relevance should be given (e.g. reduction of generation capacity needed). Flexibility is mentioned in several bullet points	Noted, we did not mention sufficiency as a separate bullet, as it is an example of behaviour change (4th bullet, eg reduce car use). Efficiency is indeed mentioned in multipe bullets, as it can be achieved in different ways (i.e., technology or behaviour change) - the bullets reflect type of behaviour change rather than type of fossil energy reduction strategy	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
2869	66	9	66	11	sustainable consumption can have significant effects on GHG emissions. Please provide a reference	accepted, reference included above the table	Leonardo Barreto	Head of center "EU&International"	Austria
71673	66	9	66	13	Products and services with low GHG emissions could get more relevance in the chapter. Zero/low carbon scenarios might require reduction of emission from the agricultural sector which are hard to achieve without changing behavior	Noted,behaviour change is included as the 4th bullet. Please note that this is also discussed in the other sectoral chapters, including Chapter 7 (on agriculture)	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
3481	66	14	66	14	Please, add a new bullet saying "- End users can select buildings made with high durability materials such as reinforced concrete (service life longer than 100 years) manufactured with low carbon cements (with a high amount of additions and a low clinker content) able to absorb carbon dioxide from the atmosphere (Xi et al 2016; Sanjuán et al 2019; Sanjuán et al 2020)." Xi, F.; Davis, S.J.; Ciais, P.; Crawford-Brown, D.; Guan, D.; Pade, C.; Shi, T.; Syddall, M.; Lv, J.; Ji, L.; et al. Substantial global carbon uptake by cement carbonation. Nat. Geosci. 2016, 9, 880–883. https://doi.org/10.1038/NGEO2840 Sanjuán, M.Á.; Estévez, E.; Argiz, C. Carbon Dioxide Absorption by Blast-Furnace Slag Mortars in Function of the Curing Intensity. Energies 2019, 12(12), 2346; https://doi.org/10.3390/en12122346 Sanjuán, M.Á.; Andrade, C.; Mora, P.; Zaragoza, A. Carbon Dioxide Uptake by Cement-Based Materials: A Spanish Case Study. Appl. Sci. 2020, 10, 339. https://doi.org/10.3390/app10010339	Noted, this is covered in the third and last bullet	Miguel Angel Sanjuán	IECA	Spain
10371	66	14	66	14	Please, add a new bullet saying "- End users can select buildings made with high durability materials such as reinforced concrete (service life longer than 100 years) manufactured with low carbon cements (with a high amount of additions and a low clinker content) able to absorb carbon dioxide from the atmosphere (Xi et al 2016; Sanjuán et al 2019; Sanjuán et al 2020)." Xi, F.; Davis, S.J.; Ciais, P.; Crawford-Brown, D.; Guan, D.; Pade, C.; Shi, T.; Syddall, M.; Lv, J.; Ji, L.; et al. Substantial global carbon uptake by cement carbonation. Nat. Geosci. 2016, 9, 880–883. https://doi.org/10.1038/NGEO2840 Sanjuán, M.Á.; Estévez, E.; Argiz, C. Carbon Dioxide Absorption by Blast-Furnace Slag Mortars in Function of the Curing Intensity. Energies 2019, 12(12), 2346; https://doi.org/10.3390/en12122346 Sanjuán, M.Á.; Andrade, C.; Mora, P.; Zaragoza, A. Carbon Dioxide Uptake by Cement-Based Materials: A Spanish Case Study. Appl. Sci. 2020, 10, 339. https://doi.org/10.3390/app10010339	Noted, this is covered in the third and last bullet	Aniceto Zaragoza	Oficemen	Spain

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
11527	66	14	66	14	Please, add a new bullet saying "- End users can select buildings made with high durability materials such as reinforced concrete (service life longer than 100 years) manufactured with low carbon cements (with a high amount of additions and a low clinker content) able to absorb carbon dioxide from the atmosphere (Xi et al 2016; Sanjuán et al 2019; Sanjuán et al 2020)." Xi, F.; Davis, S.J.; Ciais, P.; Crawford-Brown, D.; Guan, D.; Pade, C.; Shi, T.; Syddall, M.; Lv, J.; Ji, L.; et al. Substantial global carbon uptake by cement carbonation. Nat. Geosci. 2016, 9, 880–883. https://doi.org/10.1038/NGEO2840 Sanjuán, M.Á.; Estévez, E.; Argiz, C. Carbon Dioxide Absorption by Blast-Furnace Slag Mortars in Function of the Curing Intensity. Energies 2019, 12(12), 2346; https://doi.org/10.3390/en12122346 Sanjuán, M.Á.; Andrade, C.; Mora, P.; Zaragoza, A. Carbon Dioxide Uptake by Cement-Based Materials: A Spanish Case Study. Appl. Sci. 2020, 10, 339. https://doi.org/10.3390/app10010339	Noted, this is covered in the third and last bullet	PEDRO MORA PERIS	UNIVERSITY	Spain
73983	66	14	66	15	this sentence is confusing. needs to be rewritten.	accepted, we edited the text	Heleno Miguel	Lawrence Berkeley National Laboratory	United States of America
10645	66	17	67	32	While this passage makes rather pleasant reading, after one has been reading it it is difficult to remember what it was about. Possibly the strong idea is that climate is a common good and therefore people who care about climate are people who care about others. However this deserves perhaps a deep debate which is far from limited to an Energy Systems perspective...	Noted, each section starts with the main message	Philippe Waldteufel	CNRS	France
70225	66	17	66	24	The paragraph on demand-side options may also discuss timing of electric vehicle charging (https://www.sciencedirect.com/science/article/pii/S0301421510009389?via%3Dihub) , and whether drivers of plug-in hybrid vehicles choose to charge or refuel (https://dx.doi.org/10.1021/acs.est.0c03796). This would help make the link to the transport chapter more clear.	Noted, this is covered in the second bullet. Unfortunately, we have too limited space to include more examples.	Paul Wolfram	Yale University	United States of America
71675	66	17	66	24	Factors and reasons for costs and benefits of demand side mitigation options are very general and not priotized, reasons for the adoption should not only be explained but priotized in relation to their impact on emission reduction.	Noted, we indicate that different people prioritise different costs and benefits differently, depending on their values. We have no space to discuss this in a comprehensive way, unfortunately	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
14819	66	21	66	22	I'm not sure that this is a correct interpretation of Dubois et al. (2019), who assessed technology preferences in the context of electricity generation but did not consider low-carbon diets. This aspect has been investigated by other studies such as Pettifor et al. (2020), https://doi.org/10.1016/j.erss.2019.101422, and Eker et al. (2019), https://doi.org/10.1038/s41893-019-0331-1	Noted, the paper does discuss the role of culture, but we now include a reference that studied the role of culture more specifically	Marc Jaxa-Rozen	University of Geneva	France
71677	66	25	67	32	Explanation of the relevance of beliefs, values, perception of measures and social implementation of mitigation measures could be improved. Which points improve the apdoption of measures (e.g. financial resources, individual benefits, knowledge about measures, feel good factor). Which points are barriers and how can they be overcomed.	Noted. As indicated, all factors can play a role, but the extent to which they affect behaviour differs across individuals and behaviours.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
28957	66	28	66	28	Add after (Stern 2018) , or information access on subsidy schemes as well as technical knowledge on energy technologies and energy-related practices (Refer to Bartiaux 2016: Social diffusion of energy-related practices and representations: Patterns and policies in Portugal and Belgium)	Noted, please note that this sentence discusses the role of income, the effect of information is discussed insection 6.7.6.1	Fabian Heymann	INESC TEC	Switzerland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
43593	66	30	66	30	Remove second bracket	editiorial. Noted	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy
71679	66	33	66	41	Next to general goals and values of people trust in institutions and actors is of high relevance for the adoption of measures. The role of trust and transparency in defining and implementing mitigation measures should be included in this paragraph as well.	Noted, the role of trust is discussed in section 6.7.6.2	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
52237	66	38	66	39	Not clear what is meant by the comment on different values and not have the goal to maximize self-interest.	Accepted, we revised the text	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
5375	66	43	66	43	replace "renewable" by "low carbon"	Accepted, changed accordingly	Michel SIMON	Retraité/ Pdt d'association	France
2871	67	28	67	32	New social innovations are emerging, which can be harnessed to engage citizens to advance the transition towards low-carbon energy systems. This includes involvement of citizens in energy planning deliberations and decision-making, participatory budgeting, involvement in energy communities and other cooperative approaches, involvement in building retroffiting projects, participation in living labs, crowdfunding, digital social markets, idea banks and other initiatives.	Noted, these interventions/strategies for change are discussed in 6.7.6.1 and 6.7.6.2.	Leonardo Barreto	Head of center "EU&International"	Austria
29911	67	33	69	1	Consider to incorporate cumulative energy demand pr MWh across relevant energy technologies, and e.g. include one of the figures in Modahl el al. (2013) to examplify the energy demand across technoogies - see also comments to Tab 6.1. (https://www.sciencedirect.com/science/article/pii/S0301421513009294?via%3Dihub)	Noted	Government of Norway	Norwegian Environment Agency	Norway
10647	67	34	67	39	This table 6.9 is packed with valuable information but difficult to read (very small font)	This section has been re-written and a new figure provided, as well as illustrative examples of cost of mitigation. We refer the reader to the new version.	Philippe Waldteufel	CNRS	France
55789	67	34	67	39	Table 6.8 and 6.9 are currently very hard to read. It would be helpful to summarize the main findings of the two figures in the text, since both show a great deal of information and complexity. Secondly, authors have shown LCOE of various forms of energy generation in Table 6.8, but the preceding section addresses demand-side mitigation options. Can the authors provide at least notional amounts for costs of demand side options vs. supply-side options?	This table has now been revised.	Government of United States of America	U.S. Department of State	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
62007	67	34	67	34	Cost variation of different energy prodction is referred as "Table 6.8 summarises the costs of electricity generation from different sources." this does not take into account the system costs. See e.g. Sasse & Trutnevyte 2020 (Sasse, JP., Trutnevyte, E. Regional impacts of electricity system transition in Central Europe until 2035. Nat Commun 11, 4972 (2020). https://doi.org/10.1038/s41467-020-18812-y) LCOE does not include technical system feasibility in terms of hourly operation, transmission, and storage. If we assume that we heve much wind in the system, we need either storage or other backup electricity generating means for the hours there is no wind. Therefore we can not state that LCOE is the only cost tha matters. Suggest changing to e.g. "In addition to find the optimum balance between different electricity generating options, one needs to add investment needed to technical system feasibility in terms of hourly operation, transmission, and storage (Sasse and Trutnevyte, 2020). "	This table has now been revised.	Esa Vakkilainen	LUT University, Lappeenranta	Finland
1575	68	1	68	3	Table 6.8 is a complete mess and is likely to confuse rather than inform. The large range for Solar PV is difficult to understand - possible includes residential systems as well as grid connected (should be brocken out separately as for Lazard). The 2020 average LCOE of ~$90/MWh conflicts with IRENA's value of $68/MWh (weighted average for utility systems installed in 2019) and Lazard $37/MWh for a new build in 2020. The $30/MWh low for nuclear is pure fantasy. Lazard give lowest cost for a 2020 new build of $129/MWh while the IEA give the lowest cost for 2020 in China of $65/MWh. Lazard give even the "marginal cost of operation" (no capital costs) of nuclear as $25-32/MWh; perhaps this is to what the $30/MWh refers? If so, needs to be broken out seperately, as for coal and gas. The mid-nuclear cost of $115/MWh is below Lazard's lowest cost of $129/MWh with Lazard putting the average cost at $163/MWh. The "Natural gas CC with CCS" of $50-65/MWh (average $57/MWh?) is way too low. Lazard give GCC without CCS of $44-73/MWh ($59/MWh average) suggesting the CCS is free!! The IEA gives $55-90/MWh without CCS (CCS now negatively priced). Perhaps "without CCS" was meant?	While the reviewer is correct that we are missing systems costs, the purpose of this difure is just to provide ranges of LCOEs from different sources, both from current levels and their future projections and discuss key emerging messages.	Martin Green	UNSW Sydney	Australia
2687	68	1			I find it surprising that the lower end of wind LCOE remains unchanged in the future. Maybe this is due to the Figure being under development.	This section has been re-written and a new figure provided, as well as illustrative examples of cost of mitigation. We refer the reader to the new version.	Jan Wohland	ETH Zurich	Switzerland
21039	68	1	68	1	About "[…] of the key energy technologies.": please state whether the cost shown include the cost of backup and intermitttency mitigation.	This section has been re-written and a new figure provided, as well as illustrative examples of cost of mitigation. We refer the reader to the new version. We now include only very recent estimates, namely for solar and wind where costs have declined rapidly in the last years.	Government of France	Ministère de la Transition écologique et solidaire	France
43595	68	1	68	2	Is it possible that this graph is based onestimates of costs from very recent publications as well as ones published seversl years ago? For some technologies - tipically solar PV, using cost estimates spanning across a decade or longer will result in a very wide range of estimates and, more importantly, it will mask the fact that costs are plummetting in recent years. Consider restricting estimated used to the last 5 years.	This section has been re-written and a new figure provided, as well as illustrative examples of cost of mitigation. We refer the reader to the new version. We now include only very recent estimates, namely for solar and wind where costs have declined rapidly in the last years.	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
47849	68	1	68	5	Why does Table 6.8 not include bioenergy/power with CCS options? The data is available and was presneted in the chapter earlier. It should be included for completion.	This section has been re-written and a new figure provided, as well as illustrative examples of cost of mitigation. We refer the reader to the new version. We now include only very recent estimates, namely for solar and wind where costs have declined rapidly in the last years.	Patrick Lamers	NREL	United States of America
48137	68	1	68	1	Table 6.8. Please update cost numbers using data from Lazard (2020) https://www.lazard.com/media/451419/lazards-levelized-cost-of-energy-version-140.pdf	This section has been re-written and a new figure provided, as well as illustrative examples of cost of mitigation. We refer the reader to the new version. It now include bio-electricity and strategies with CCS.	Mark Jacobson	Stanford University	United States of America
55791	68	1	68	1	Table 6.8 needs to be rethought for solar PV, CSP, and wind. This appears to be mixing different types of systems and applications. The only way to have such high cost PV, for example, is at remote sites. This should be clearly identified and these applications separated, then separately compared to the other systems for similar applications, such as remote diesel gensets for solar PV. Similarly for CSP, wind, etc. Nuclear does not have the issue of remote sites; the costs indicated likely reflect the current range of costs.	This section has been re-written and a new figure provided, as well as illustrative examples of cost of mitigation. We refer the reader to the new version. We now include only very recent estimates, namely for solar and wind where costs have declined rapidly in the last years.	Government of United States of America	U.S. Department of State	United States of America
71681	68	1	68	3	Low LCOE levels for Wind should also decrease in future times (as is the case for PV for example), current average level seems also to high, e.g. IEA estimates 50 USD/MWh as a median	This section has been re-written and a new figure provided, as well as illustrative examples of cost of mitigation. We refer the reader to the new version. We now include only very recent estimates, namely for solar and wind where costs have declined rapidly in the last years.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
71683	68	1	68	3	Cost estimated for current and 2030 nuclear power plants seems far to optimistic considering current new build power plants	This section has been re-written and a new figure provided, as well as illustrative examples of cost of mitigation. We refer the reader to the new version. We now include only very recent estimates, namely for solar and wind where costs have declined rapidly in the last years.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
71685	68	1	68	3	Upper end of solar PV seems not in line with current small scale rooftop installations (probarbly defining the upper end of costs in 2020)	This section has been re-written and a new figure provided, as well as illustrative examples of cost of mitigation. We refer the reader to the new version. We now include only very recent estimates, namely for solar and wind where costs have declined rapidly in the last years.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
74207	68	1	68	3	This section includes existing fully depreciated coal and new coal plants, but does not include the same analysis for nuclear. Given that nuclear units can run for up to 80 years, this cost comparison is needed, othewise the cost for nuclear is not a accurate measure of the long term costs. https://www.world-nuclear.org/information-library/economic-aspects/economics-of-nuclear-power.aspx	This section has been re-written and a new figure provided, as well as illustrative examples of cost of mitigation. We refer the reader to the new version. We now include only very recent estimates, namely for solar and wind where costs have declined rapidly in the last years.	Jeffrey Merrifield	Pillsbury Law Firm	United States of America
75753	68	1	68	1	Data presented in Table 6-8 for nuclear power are dubious. Based on data presented, no reduction in LCOE from nuclear is expected in the future. Yet, on page 35, line 44 - line 46 of the same report price LCOE for new builds is expected to be in the range 42 USD - 102 USD/MWh which is in contradiction with range 50 - 200 given in Table 6-8. The table is reffered to as a summary. My question is - summary of what, certainly not of data given in the previous sections.	This section has been re-written and a new figure provided, as well as illustrative examples of cost of mitigation. We refer the reader to the new version. We now include only very recent estimates, namely for solar and wind where costs have declined rapidly in the last years.	Krešimir Trontl	University of Zagreb, Faculty of Electrical Engineering and Computing	Croatia

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
77107	68	1	68	30	Table 6.8 on comparing various power source costs is idealistic; there is no comprehension of the major connection costs for adding renewables (including transmission and distribution system re-configuration), nor of the costs of having conventional rapid-response gas-fired generation to compensate for the unpredictable swings in renewable supply. That is why consumer energy costs increase linearly with the extent of renewables on the system. These additional costs will multiply further with the phased electrification of transport and heating.	This section has been re-written and a new figure provided, as well as illustrative examples of cost of mitigation. We refer the reader to the new version. We now include only very recent estimates, namely for solar and wind where costs have declined rapidly in the last years.	Jim O'Brien	Expert Reviewer AR6 SOD WG1	Ireland
80451	68	1	68	1	This figure (which I understand is under development) should reflect the data shown elsewhere in the report, for example in figure 6.8 for solar, with the spread being the 10th/90th percent percentile in 2019 (maybe 2020, if time allows for an update) AND the capacity-weighted global averages for utility scale installations, along with cost reduction estimates e.g. https://www.irena.org/publications/2020/Apr/Global-Renewables-Outlook-2020. Note: The company Lazard (asset management and financial advice) has been publishing reports on levelized cost of energy/electricity and storage for a few years, which contains information that could help for figure: https://www.lazard.com/perspective/levelized-cost-of-energy-and-levelized-cost-of-storage-2020/ Lazard’s report suggestions that the cost for unsubsidised renewables is in the range, sometimes even lower than the marginal cost of existing coal, nuclear, gas power generation (confirming what 6-25 line 5 says for solar vs fossil fuels). The low cost for CSS, a technology, so far only few full scale plants ever have been built, is hard to compare to existing large scale deployments. Also, CCS plants built over the past 20 years have a ~7% growth rate, less than half of the average across scenarios shown in figure 2.30 (2-76) and still face many technological challenges.	While the reviewer is correct that we are missing systems costs, the purpose of this difure is just to provide ranges of LCOEs from different sources, both from current levels and their future projections and discuss key emerging messages.	Moritz Riede	University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
86597	68	1	68	3	This table is very poor science. There is no sources provided for the data. The values for solar and wind do not match the 2019 low, mid and high estimates shown in Figures 6.8, likewise the wind data does not match 6.11. The cost of CCGT is missing but the mid range should be around $40-50 $/MWh (Lazard & Advanced CCGT" near-term projection EIA). How then is CCGT with CCS at $55/MWh when it is stated clearly in the section 6.4.2.5 that capex and opex are about double. Where also is the uncertainty in this value given there are no CCGT with CCS plants currently operating on earth today? Also, I am curious to know where on earth is a nuclear power plant operating at $30/MWh? I genuinely hope this is not the cost characteristics being used by the IAMs in Section 6.6 and 6.7 but I suspect it is as the modelling results appear to be quite bullish on CCS and bearish in renewables which reflects the disconnect in this Table with the empirical evidence. See Way, R., Mealy, P., Farmer, J. D. D., Way, Mealy, P., Farmer, J. D. D., Way, R., Mealy, P., & Farmer, J. D. D. (2020). Estimating the costs of energy transition scenarios using probabilistic forecasting methods (No. 2021–01). https://www.inet.ox.ac.uk/publications/no-2021-01-estimating-the-costs-of-energy-transition-scenarios-using-probabilistic-forecasting-methods/ for an exhaustive analysis of the data and trends)	This section has been re-written and a new figure provided, as well as illustrative examples of cost of mitigation. We refer the reader to the new version. We now include only very recent estimates, namely for solar and wind where costs have declined rapidly in the last years.	Matthew Ives	University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
17387	68	2	68	3	Table 6.6: no difference between dispatchable and non-dispatchable sources (see example of similar table in Annual Energy Outlook of US EIA). Proposal: Separate dispatchable and non-dispatchable sources like US EIA.	This section has been re-written and a new figure provided, as well as illustrative examples of cost of mitigation. We refer the reader to the new version. We now include only very recent estimates, namely for solar and wind where costs have declined rapidly in the last years.	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
85481	68	2	68	2	Solar and wind seem very expensive here. I would advise to use a combination of Lazard (the gold standard), IRENA and BNEF as the most trusted sources in the energy community on renewable LCEO and I would split rooftop PV and utility scale PV and onshore wind and offshore wind. For Lazard 2020 see e.g. here: https://www.lazard.com/perspective/levelized-cost-of-energy-and-levelized-cost-of-storage-2020/ I know the rule is to prefer peer reviewed but that simply can't hold a candle to these organisations that have whole teams that look at these prices year after year and get very negative feedback when they get it wrong. Beside, IRENA and BNEF are already used elsewhere (maybe Lazard too). Important warning: don't use IEA for renewable costs. IRENA was initiated partly because the IEA can't seem to get renewable prices right.	This section has been re-written and a new figure provided, as well as illustrative examples of cost of mitigation. We refer the reader to the new version. We now include only very recent estimates, namely for solar and wind where costs have declined rapidly in the last years.	Auke Hoekstra	Eindhoven University of Technology	Netherlands
12019	68	3	70	1	The table is unreadable. A simplified table with fewer categories is required.	This section has been re-written and a new figure provided, as well as illustrative examples of cost of mitigation. We refer the reader to the new version. We now include only very recent estimates, namely for solar and wind where costs have declined rapidly in the last years. We do use also IEA as a source, but we also include EIA, IRENA, NREL and several others.	Paul Rouse	Carnegie Climate Governance Initiative (C2G) - The Carnegie Council for Ethics and International Affairs	United Kingdom (of Great Britain and Northern Ireland)
12021	68	3	70	1	Reference to the governance of monitoring reporting and verification of the various techniques could usefully be included.	This table has now been revised.	Paul Rouse	Carnegie Climate Governance Initiative (C2G) - The Carnegie Council for Ethics and International Affairs	United Kingdom (of Great Britain and Northern Ireland)
30729	68	3	68	3	In table 6.8, offshore and land wind power should be separately written. Nuclear should also be seperately evaluated by "existing" and "depreciated" as fossil fuel is.	This section has been re-written and a new figure provided, as well as illustrative examples of cost of mitigation. We refer the reader to the new version. We now include only very recent estimates, namely for solar and wind where costs have declined rapidly in the last years. We do use also IEA as a source, but we also include EIA, IRENA, NREL and several others.	Government of Japan	Climate Change Division - Ministry of Foreign Affairs	Japan
78247	68	3	69	3	Misrepresented fact - Political Acceptance for nuclear energy appears to be based on qualitative judgements. The feasiblity option for nuclear should be upgraded as it is a well established source of energy with good political backing except in a few countries. In India, the political will is clearly expressed in the decision to build 10 new PHWRs in fleet mode (https://pib.gov.in/Pressreleaseshare.aspx?PRID=1539250)	This section has been re-written and a new figure provided, as well as illustrative examples of cost of mitigation. We refer the reader to the new version. We now include only very recent estimates, namely for solar and wind where costs have declined rapidly in the last years. We do use also IEA as a source, but we also include EIA, IRENA, NREL and several others.	Reetesh Chaurasia	Department of Atomic Energy, Government of India	India
17911	68				Color combination makes it hard to distinguish 2030 and 2050 values	This section has been re-written and a new figure provided, as well as illustrative examples of cost of mitigation. We refer the reader to the new version. We now include only very recent estimates, namely for solar and wind where costs have declined rapidly in the last years. We do use also IEA as a source, but we also include EIA, IRENA, NREL and several others.	Robert Brecha	Climate Analytics	Germany

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
63661	68		68		Table 6.8 - biomass electricty and CHP (with or without CCS) are not included in this table, yet there are several large scale examples of both. Both should be added to the table.	This section has been re-written and a new figure provided, as well as illustrative examples of cost of mitigation. We refer the reader to the new version. We now include only very recent estimates, namely for solar and wind where costs have declined rapidly in the last years. We do use also IEA as a source, but we also include EIA, IRENA, NREL and several others.	Government of Canada	Environment and Climate Change Canada	Canada
77239	68				It is surprising that the cost estimates for 2030 and (even more) 2050 do not reflect the reduction of costs that is anticipated by moving from FOAKs (the exceptional cases justifying the high estimate for 2020) to NOAKs (as an example, the cost of the two EPRs in UK (the third and fourth units in Europe, 5th and 6th globally) is already lower than that of the 1st (Finland) and 2nd (France) reactors).	This section has been re-written and a new figure provided, as well as illustrative examples of cost of mitigation. We refer the reader to the new version. We now include only very recent estimates, namely for solar and wind where costs have declined rapidly in the last years. We do use also IEA as a source, but we also include EIA, IRENA, NREL and several others.	Giacomo Grasso	ENEA	Italy
16943	69	0	69	0	Table too big for a page. Impossible to read anything.	Accepted, we changed the format	Government of Spain	Area de Estrategias de Adaptacion - Oficina de Cambio Climatico - Ministerio de la Transicion Ecologica	Spain
21041	69	0	69	0	"in case...construction" on 9th column: Surprising that this limitation is not also given for wind and solar. The surface needed for nuclear is very small compared to those.	Noted. this comment aligns with our revised characterization of solar land use as a barrier in the revised table.	Government of France	Ministère de la Transition écologique et solidaire	France
21043	69	0	69	0	9th column "normally, ...utilisation": Consider removing "normally". The storage of radioactive waste has little impact on Land Use and should ot be mentionned here.	Noted. The comment aligns with the text, what it mentions in addition, is that some authors point out to the longevity of land occupation of long-term disposal of high level radiactive waste, but the footprint is still very low.	Government of France	Ministère de la Transition écologique et solidaire	France
21045	69	0	69	0	About "needs substantive...purposes": Water cooling is an option, but not needed. Palo Verde nuclear PP in the US runs on city waste waeter.	Noted. Majority of nuclear power plants use water for their cooling purposes.	Government of France	Ministère de la Transition écologique et solidaire	France
21047	69	0	69	0	About "can be...facilities": Should be "Significant but can be minimized..."	Noted. Text has been corrected	Government of France	Ministère de la Transition écologique et solidaire	France
21049	69	0	69	0	About "concerns in protected areas": Significant impact because of the rrequired surfaces.	Noted. The assessment does consider land use requirements.	Government of France	Ministère de la Transition écologique et solidaire	France
21051	69	0	69	0	About "globally beneficial": The "Effects on health and wellbeing" is acurrately so "Globally beneficial" for Solar, but why is it not for hydropower or nuclear ?	Noted. No supporting literature for globally beneficial health effects	Government of France	Ministère de la Transition écologique et solidaire	France
21053	69	0	69	0	"opposed by fossil interests": please add other examples/obstacles to wind farm projects as this one is not the only one	Accepted. Text has been modified	Government of France	Ministère de la Transition écologique et solidaire	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
21055	69	0	69	0	"everything is falling behind the schedule": such generalization requires very sound literature backups. Consider rewording, if there is no absolute certainty that this applied to "everything"	Accepted. Text was revised.	Government of France	Ministère de la Transition écologique et solidaire	France
21079	69	0	69	0	3rd colunn "Limited in urban areas": In many cases (see Germany as an example in the reference), solar PV uses a lot of area compared to conventional electricity generation (including nuclear). This land requirement may be an issue in densely populated areas. This must be stated Vasilis Fthenakis, Hyung Chul Kim, Land use and electricity generation: A life-cycle analysis, Renewable and Sustainable Energy Reviews,Volume 13, Issues 6–7,2009,Pages 1465-1474,ISSN 1364-0321, https://doi.org/10.1016/j.rser.2008.09.017	Noted. this comment aligns with our revised characterization of solar land use as a barrier in the revised table.	Government of France	Ministère de la Transition écologique et solidaire	France
28621	69	0	69	0	This table is hard to read and to understand	Accepted, we changed the format	Tim Dixon	IEAGHG	United Kingdom (of Great Britain and Northern Ireland)
28623	69	0	69	0	The cell for Water and Carbon Dioxide Capture should be light brown not dark brown, to reflect the point on water usage evidence above. The water use of CO2 capture can be managed to not increase, see references: Giannaris, S. et al (2020). "Implementing a second generation CCS facility on a coal fired power station", Greenhouse Gases: Science and Technology, 10(3), 506-518; Magneschi et al (2017) "The Impact of CO2 Capture on Water Requirements of Power Plants", GHGT-13, Energy Procedia 114 6333-6347 ; IEAGHG (2020) "Understanding the cost of reducing water usage in coal and gas fired power plants with CCS", IEAGHG 2020-09; IEAGHG (2011) "Evaluation and Analysis of Water Usage of Power Plants with CO2 Capture" IEAGHG 2010/05; IEAGHG (2020) "CCS and the Sustainable Development Goals", IEAGHG 2020-14; also IPCC (2018) SR1.5 Chap 5 p500 which cites Magneschi.	Accepted. We have changed this in the text already	Tim Dixon	IEAGHG	United Kingdom (of Great Britain and Northern Ireland)
28625	69	0	69	0	The cell for Maturity and Technology Readiness should be light brown or yellow. CCS technologies are proven at large-scale. See GCCSI Global Status Report (2019), IEAGHG reports 2015-06 Boundary Dam project, 2018-05 Port Arthur project, 2019-04 Quest project.	We agree that some parts of the CCS supply chain have been proven at large-scale. However, others have not been based on the peer-reviewed literature: Vishal, V., Chandra, D., Singh, U., & Verma, Y. (2021). Understanding initial opportunities and key challenges for CCUS deployment in India at scale. Resources, Conservation and Recycling, 175, 105829., Bui, M., Adjiman, C. S., Bardow, A., Anthony, E. J., Boston, A., Brown, S., ... & Mac Dowell, N. (2018). Carbon capture and storage (CCS): the way forward. Energy & Environmental Science, 11(5), 1062-1176.	Tim Dixon	IEAGHG	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
28627	69	0	69	0	The cell for Legal and Administrative Feasibility and Carbon Dioxide Capture should be yellow. There are mature regulations for CCS monitoring and proven technologies for CCS monitoring, see: Dixon et al (2015) "Legal and regulatory developments on CCS", International Journal on Greenhouse Gas Control 40 (2015) 431-448 (SI to review 10 years since IPCC SR on CCS); Jenkins et al (2015) "The state of the art in monitoring and verification - Ten years on", International Journal of Greenhouse Gas Control 40 (2015) 312-349 (SI to review 10 years since IPCC SR on CCS); Dixon and Romanak (2015), "Improving monitoring protocols for CO2 geological storage with technical advances in CO2 attribution monitoring", International Journal of Greenhouse Gas Control 41 (2015) 29-40.	Noted. The table has been redesigned.	Tim Dixon	IEAGHG	United Kingdom (of Great Britain and Northern Ireland)
30731	69	0	69	0	The letters of table 6.9 is too small and should be fixed.	Accepted, we changed the format	Government of Japan	Climate Change Division - Ministry of Foreign Affairs	Japan
30765	69	0	69	0	The text in Table 6.9 is too small to read. This is an important table, so it should be a more clear and understandable table or figure.	Accepted, we changed the format	Government of Japan	Climate Change Division - Ministry of Foreign Affairs	Japan
48009	69	0	69	0	In Table 6.9, the water quality and quantity indicator assumes a necessary negative impact (dark brown) on the feasibility of bioenergy as a mitigation option. However, as described in Chapter 3, "increased use of bioenergy could have positive or negative effects on water quality depending on the feedstock, management practice and prior land use" (Chapter 3, p. 97, l. 27-29). Also, it is worth mentioning an additional reference, which the authors of this chapter are invited to carefully consider: Næss, Jan & Cavalett, Otavio & Cherubini, Francesco. (2021). The land–energy–water nexus of global bioenergy potentials from abandoned cropland. Nature Sustainability. 10.1038/s41893-020-00680-5. Therefore, the correct water quality/quantity indicator for bioenergy is light brown (mixed positive and negative effect). This should be corrected in the table.	The feasibility table has been corrected to reflect to possible positive or negative impact of bioenergy on water quantity and quality in line with Chapter 3	Marcelo moreira	UNICAMP - Agroicone	Brazil
50929	69	0	69	0	In Table 6.9, the water quality and quantity indicator assumes a necessary negative impact (dark brown) on the feasibility of bioenergy as a mitigation option. However, as described in Chapter 3, "increased use of bioenergy could have positive or negative effects on water quality depending on the feedstock, management practice and prior land use" (Chapter 3, p. 97, l. 27-29). Also, it is worth mentioning an additional reference, which the authors of this chapter are invited to carefully consider: Næss, Jan & Cavalett, Otavio & Cherubini, Francesco. (2021). The land–energy–water nexus of global bioenergy potentials from abandoned cropland. Nature Sustainability. 10.1038/s41893-020-00680-5. Therefore, the correct water quality/quantity indicator for bioenergy is light brown (mixed positive and negative effect). This should be corrected in the table.	The feasibility table has been corrected to reflect to possible positive or negative impact of bioenergy on water quantity and quality in line with Chapter 3	Government of Brazil	Ministry of Foreign Affairs of Brazil	Brazil

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
64619	69	0	69	0	Table 6.9 is so packed with illegible small print as serving no purpose whatsoever. Regrettable, as it seems to contain useful and interesting information and insights.	Accepted, we changed the format	Government of Netherlands	Ministry of Economic Affairs and Climate Policy	Netherlands
85787	69	0	69	0	Suggest simplifying this table. Appreciate that the authors have attempted to synthesis a large amount of information into a table format, however this table is very difficult to read.	Accepted, we changed the format	Government of Australia	Department of Industry, Science, Energy and Resources	Australia
2689	69	1			Unclear what the values of LoA and LoC mean. What does 5 stand for?	Noted. The figure has been adapted and the caption indicates the meaning of LoC, we now longer refer to LoA.	Jan Wohland	ETH Zurich	Switzerland
17199	69	1	69	1	Table 6.9 seems important, but is totally illegible and cannot be reviewed	Accepted, we changed the format	William Lamb	Mercator Research Institute on Global Commons and Climate Change (MCC)	Germany
17389	69	1	69	1	Table 6.9: system integration costs and storage costs of wind and solar are moved into separate columns.Results: wind and solar columns are very bright (high grades). However, unlike most of the other sources and actions, they are very tightly connected to storage and system integration.	Noted. Storage is assessed as a separate option. Chapther 3 assess the feasibility of different pathways, including a set of options; in this chapter, we assess the feasibility of options separately	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
17391	69	1	69	1	Simplicity and global scalability is claimed for solar and wind. It is simple for a smaller installations. But it is far from simple and scalable when one needs to integrate large quantities of wind and solar into the system and to store the excess energy needed for low-wind, no-sun conditions.	Noted. All options face feasibility challenges when implemented at a very large scale, this is acknowledged in the SPM as well	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
17393	69	1	69	1	Low costs of wind and solar: yes - without storage and integration. Storage and integration costs in the columns on the right hand side of the table are marked as low (brightest color). Which is not true. Simple scalling of the current costs of Tesla batteries show that these are very expensive options. Significant electric grid upgrades are costly too.	Noted. Storage is assessed as a separate option. Chapther 3 assess the feasibility of different pathways, including a set of options; in this chapter, we assess the feasibility of options separately	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
17395	69	1	69	1	water needed in case of high solar CSP generation are neglected (bright color) but are "darker" for nuclear.	Noted. CSP deployment is much smaller than PV so water use for solar (CSP + PV) is not a barrier.	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
17397	69	1	69	1	scalability of nuclear is disputed because of the need for qualified and skilled labor force. What kind of future is foreseen: large numbers of poorly skilled workers intalling and maintaining PV and wind turbines, or much smaller number of highly skilled staff? I would not punish nuclear because of that. This remark should be deleted and color changed to brightest.	Noted. We base the assessment on the literature	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
17399	69	1	69	1	wind and solar political acceptance: "Opposed by fossil interests", After two decades of wind and solar development, It is rather clear that wind and sun cannot replace fossil fuels. Energiewende is a clear proof of that claim. Thus, it is actually the oposite: fossil interests support wind and solar as a way to battle nuclear and hydro.	Noted. We base the assessment on the literature, which indicates that this is a barrier	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
17401	69	1	69	1	"Lack of political acceptance" for nuclear - that depends on the country. There are also countries where other sources are not acceptable. So the color should not be dark but intermediate.	Accepted, the text has been revised	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
17403	69	1	69	1	nuclear institutional capability: "Lenghty licence process, not enough institutions and what they have created is not a sustainable process since everything is falling behind the schedule". Even if falling behind the schedule is true, it is impossible to deny the fact, that in two similar countries, France and Germany, France managed to decarbonize their electricity with nuclear in two decades, while Germany three decades later did a rather poor job with wind and solar in a similar period. So the color of this criteria is wrong in my opinion.	Accepted. The text has been revised	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
17405	69	1	69	1	Legal feasibility of nuclear is dark without explanation. It depends on the country. In several countries this is a legal option and so the color should be medium dark	Accepted. The text has been revised	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
17407	69	1	69	1	nuclear physical potential: "In case of expansion of nuclear (doubling or tripling of current capacity levels), some countries could face limits in finding new sites for construction". This is definitely not a physical limitation but a social one. From the stanpoint of physics it is much easier to find locations for the same amount of nuclear electricity than for wind, solar or any other source. Thus, nuclear should have the lightest color here, while other sources should be probably darker.	Accepted. The text has been revised	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
17409	69	1	69	1	storage column. Units are GW. Storage capacity should be measured in TWh and not in GW. Energy is more relevant than power.	Irrelevant. In the table there is not any index with unit.	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
17411	69	1	69	1	In my opinion Table 6.9 needs EROI index for all sources. EROI for wind and solar it should include storage and transmission.	Noted, unfortunately this was out of the scope of the table.	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
17413	69	1	69	1	In my opinion Table 6.9 and chapter 6 should take into account raw material requirements. Reference: Junne et. al. Critical materials in global low-carbon energy scenarios: The case for neodymium, dysprosium, lithium, and cobalt, Energy, Volume 211, 2020, 118532, ISSN 0360-5442, https://doi.org/10.1016/j.energy.2020.118532. "The maximum annual primary material demand of the scenarios exceeds current extraction volumes by a factor of 3 to 9 (Nd), 7 to 35 (Dy), 12 to 143 (Li), and 2 to 22 (Co).... Average resource estimates of Li and Co are exceeded by up to a factor of 2.1 and 1.7, respectively. "	Noted, this is included in the geophysical dimension of feasibility	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
17415	69	1	69	1	In my opinion Table 6.9 needs additional row: reliability of electricity supply in extreme circumstances.	Rejected, we explain the rationale of the assessment approach in the TS	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
18251	69	1	69	1	(TABLE 6.9) (i) The biodiversity indicators associated with bioenergy are much broader than just water - this cell in the table should include (for example) habitat loss, reduced connectivity, invasive species impacts, etc. (ii) The biodiversity indicators associated with solar should include land use / habitat loss. (iii) The biodiversity indicators associated with nuclear should include potential devastating toxic impacts on species and ecosystems associated with improper waste disposal. (iv) The biodiversity indicators associated with CCUS are unlikely to be 0 across the board, given that impacts on biodiversity will depend on the specific carbon storage technology used. It would be more accurate to say that there is no evidence or insufficient research in this area rather than state zero impact.	Noted. Indeed, we assessed broader impacts on biodiversity. Impacts on land use are assessed under the geophysical dimension.Toxic waste is assessed under environmental-ecological feasibility. See Annex B A.B.12 for a detailed description of the assessment method	Government of United Kingdom (of Great Britain and Northern Ireland)	Department for Business, Energy & Industrial Strategy	United Kingdom (of Great Britain and Northern Ireland)
28363	69	1	69	1	Table 6.9 is not readable in the printed document. It should be separated into different tables having much large font size.	accepted, we changed the format	Sevostian Bechta	KTH-Royal Institute of Technology	Sweden
28365	69	1	69	1	Table 6.9: “The line Physical potential” should be revised for Nuclear Power. The current text (“In case of expansion of nuclear (doubling or tripling of current capacity levels), some countries could face limits in finding new sites for construction.”) is not about physical potential. Other power industries, including solar and wind, have similar, if not stronger, limits for similar installed capacity. Alternative version is suggested: “Physical potential of the nuclear power is determined by its fuel cycle and reactor technology. Current generation (Gen II and III) represented in majority by Light Water Reactors (LWRs) uses uranium- based open fuel cycle and its physical potential relates to Uranium resources, which are sufficient for substantial growth of nuclear power [1]. Closed fuel cycle [2] together with fast breeder reactors of Gen IV [3] and thorium-based fuel cycle [4] makes nuclear power self sustainable.” 1. URANIUM 2020: RESOURCES, PRODUCTION AND DEMAND, NEA No. 7551, © OECD 2020. 2. IAEA-TECDOC-1639: Assessment of Nuclear Energy Systems Based on a Closed Nuclear Fuel Cycle with Fast Reactors. A report of the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO). 3. Handbook of Generation IV Nuclear Reactors. Woodhead Publishing Series in Energy, 2016, Pages 879-911. 4. INTRODUCTION OF THORIUM IN THE NUCLEAR FUEL CYCLE, NEA No. 7224, © OECD 2015.	Accepted. The text has been revised	Sevostian Bechta	KTH-Royal Institute of Technology	Sweden
28367	69	1	69	1	Table 6.9/Nuclear energy/Water quantity and quality: "Needs substantive amount of water for cooling purposes". The statement contradicts to the fact that some operating NPPs use cooling towers [1], i.e. air-cooling. Increase of thermal efficiency of modern reactors from the 33% to 36–39% (and even higher in perspectives) [1] reduces the amount of water necessary for cooling. 1. Efficient water management in water cooled reactors. — Vienna : International Atomic Energy Agency, 2012.	Accepted. The text has been revised	Sevostian Bechta	KTH-Royal Institute of Technology	Sweden
28369	69	1	69	1	Table 6.9/Nuclear energy/political acceptance, The statement about "Lack of political acceptable" contradicts to the reality. Political acceptance of nuclear energy exists in many countries, actually, where majority of world population lives. The statement should be excluded or revised in the opposite way and the cell colour should be changed accordingly.	Accepted. The text has been revised	Sevostian Bechta	KTH-Royal Institute of Technology	Sweden

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
28371	69	1	69	1	Table 6.9/Nuclear energy/Institutional capacity and governance, The statement: "Lenghty licence process, not enough institutions and what they have created is not a sustainable process since everything is falling behind the schedule" is very speculative and unclear. Licensing process length is very different for different designs, licensees, and regulatory authorities. It is unclear about "not enough institutions" and "everything is falling behind the schedule". I suggest to exclude this statement and its possible influence on the table and conclusions.	Accepted. The text has been revised	Sevostian Bechta	KTH-Royal Institute of Technology	Sweden
28959	69	1	69	1	Table 6.9 unreadble, take out or enlarge and increase font size significantly	accepted, we changed the format	Fabian Heymann	INESC TEC	Switzerland
29913	69	1	69	1	Please find a better way to make the information in Table 6.9 accesible for the readers.	accepted, we changed the format	Government of Norway	Norwegian Environment Agency	Norway
31483	69	1	69	1	Table 6.9/Solar energy/land use, Solar PV uses a lot of land surface compared to nuclear electricity generation.	Noted. this comment aligns with our revised characterization of solar land use as a barrier in the revised table.	Carolina Ahnert	Universidad Politécnica de Madrid	Spain
31485	69	1	69	1	Table 6.9/Nuclear energy/Physical potential, Nuclear power plants needs less land than renewable energy sources as wind and solar.	Noted. The text says that nuclear power has low land requirements	Carolina Ahnert	Universidad Politécnica de Madrid	Spain
31487	69	1	69	1	Table 6.9/Nuclear energy/political acceptace, "Political acceptance is higher among those countries who perceive benefits for economy, climate change mitigation and energy security".	Noted	Carolina Ahnert	Universidad Politécnica de Madrid	Spain
31489	69	1	69	1	Table 6.9/Effects on health and wellbeing: the statement, "Globally beneficial' made for solar energy should be also applied to nuclear energy	Noted. No supporting literature for a statement on global benefits on health	Carolina Ahnert	Universidad Politécnica de Madrid	Spain
31491	69	1	69	1	Table 6.9/Nuclear energy/Institutional capacity and governance, Many nuclear projects in China, Korea, Russia, and United Arab Emirates are very much on track or have been completed on shedule	Accepted. The text has been revised	Carolina Ahnert	Universidad Politécnica de Madrid	Spain
31493	69	1	69	1	Table 6.9/Solar and Wind energy/Maturity and technology readiness, Technology of GenIII/IIII+ reactors is ready as has been demonstrated with the AP1000s and EPRs projects in China	Accepted. The text has been revised	Carolina Ahnert	Universidad Politécnica de Madrid	Spain
31495	69	1	69	1	Table 6.9/Solar and Wind energy/Maturity and technology readiness, Solar and wind energy as its generation is variable, when deployed on a large scale, it needs to be accompanied with deployment of large scale electricity/energy storage whose technology maturity is not yet ready.	Noted. Storage is assessed as a separate option. Chapther 3 assess the feasibility of different pathways, including a set of options; in this chapter, we assess the feasibility of options separately	Carolina Ahnert	Universidad Politécnica de Madrid	Spain
31497	69	1	69	1	Table 6.9/Nuclear energy/Employment effect and economic growth, "For newcomers countries to nuclear energy, the employment benefit will be more substantial beyond the constructin of the first two units"	Noted	Carolina Ahnert	Universidad Politécnica de Madrid	Spain
31499	69	1	69	1	Table 6.9/Solar energy/Cost in 2030 and long term, Solar energy should be accompanied with deployment of large scale electricity/energy storage whose cost is still quite high.	Noted. Storage is assessed as a separate option. Chapther 3 assess the feasibility of different pathways, including a set of options; in this chapter, we assess the feasibility of options separately	Carolina Ahnert	Universidad Politécnica de Madrid	Spain
31501	69	1	69	1	Table 6.9/Wind energy/Cost in 2030 and long term, Wind energy should be accompanied with deployment of large scale electricity/energy storage whose cost is still quite high.	Noted. Storage is assessed as a separate option. Chapther 3 assess the feasibility of different pathways, including a set of options; in this chapter, we assess the feasibility of options separately	Carolina Ahnert	Universidad Politécnica de Madrid	Spain
37725	69	1	69	1	Table 6.9 looks speculative. There is no lack of political will in certain countries. Level of acceptance is high in many countries.	Noted. We assess the feasiblity of options in general. Yet, we do acknowledge that assessment may differ across context, which is indicated under role of context	Ravi B Grover	Homi Bhabha National Institute	India

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
43597	69	1	69	2	The table is unreadable. Font size is too small due to the attemto to pack too much information into tiny cells. Consider splitting it in 2-3 tables (e.g fossil-fuel-based technolgies vs. carbon-free ones)	accepted, we changed the format	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy
50071	69	1	69	1	The fonts are too small to read. The layout should be reconsidered.	accepted, we changed the format	Masahiro Sugiyama	University of Tokyo	Japan
50455	69	1	69	1	consider seperating into 2 tables	accepted, we changed the format	Hoy Yen Chan	ASEAN Centre for Energy	Malaysia
51135	69	1	69	1	Table 6.9: much (much) too small font makes the table illegible in a printed report (and makes it very painfull to review!!!). It should be put in landscape format	accepted, we changed the format	Eric PROUST	European Nuclear Society (ENS)	France
51137	69	1	69	1	Table 6.9/Solar energy/land use, "Limited in urban areas": In many cases (see Germany as an example in [1]), solar PV uses a lot of area compared to conventional electricity generation (including nuclear). This land requirement may be an issue in densely populated areas. This must be stated. [1] Vasilis Fthenakis, Hyung Chul Kim, Land use and electricity generation: A life-cycle analysis, Renewable and Sustainable Energy Reviews,Volume 13, Issues 6–7,2009,Pages 1465-1474,ISSN 1364-0321, https://doi.org/10.1016/j.rser.2008.09.017	Noted. this comment aligns with our revised characterization of solar land use as a barrier in the revised table.	Eric PROUST	European Nuclear Society (ENS)	France
51139	69	1	69	1	Table 6.9/Nuclear energy/Physical potential, "In case of expansion of nuclear (doubling or tripling of current capacity levels), some countries could face limits in finding new sites for construction": 1/ this statement is of marginal significance. Indeed, this potential limitation could only concern a very small number of countries whose share of nuclear in the electricity production is already large, like France. However, these countries are unlikely to double or tripple their nuclear capacity among others because the growth of their electricity consumption will not be sufficicent to create the need for such an expansion. 2/ In fact, nuclear energy exhibits the higher physical potential among low-carbon energy sources because its several orders of magnitude highier energy density (as shown in Fig. 12.9 of this draft report). This should be reflected with appropriate coloring (yellow) 3/ Were this statement maintained, an additional statement should be introduced along similar lines for solar and wind energy since, in case of large deployment of solar or wind energy, some countries will also face limits in finding sites, in particular in densely populated areas, due to land area requirements for solar farms ans onshore wind farms	Accepted. The text has been revised	Eric PROUST	European Nuclear Society (ENS)	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
51141	69	1	69	1	Table 6.9/Nuclear energy/Water quantity and quality, "Needs substantive amount of water for cooling purposes" : add, "however, adaptation in power plant cooling technology can considerably reduce global freshwater withdrawals and thermal pollution, and seawater, not freshwater, is used for nuclear power plants located on the seaside”. The first part of the proposed addition ("however, adaptation in power plant cooling technology can considerably reduce global freshwater withdrawals and thermal pollution” is an excerpt of the abstract of Reference [1], which is a reference already cited page 36 line 24 of this Chapter 6. The second part of the proposed addition is factual. Its addition is important. Indeed, A number of countries are able to use once-through seawater cooling for all of their nuclear plants. Among these are the UK, Sweden, Finland, South Africa, Japan, Korea and China. Finally, note that, beyond freshwater and seawater, wastewater can also be used for coolign nuclear power plants. Thus, the Palo Verde Nuclear plant in the US uses the water from the treated sewage from several nearby cities to provide the cooling of the waste steam it produces [2]. [1] Fricko, O., S. C. Parkinson, N. Johnson, M. Strubegger, M. T. H. van Vliet, and K. Riahi, 2016: Energy sector water use implications of a 2 degrees C climate policy. Environ. Res. Lett., 11, https://doi.org/10.1088/1748-9326/11/3/034011 [2] https://en.wikipedia.org/wiki/Palo_Verde_Nuclear_Generating_Station	Accepted. Some half of existing nuclear power plants use inland water bodies for their cooling proceses. The text has been modified.	Eric PROUST	European Nuclear Society (ENS)	France
51143	69	1	69	1	Table 6.9/Solar energy/biodiversity, "Concerns in protected areas". Not only: it should be first stated "significant due to the required surface area (solar farms)"	Reject. Biodiversity is not a concern outside of protected areas, text indicates much co-use of solar areas for other activities inlcuding wildlife.	Eric PROUST	European Nuclear Society (ENS)	France
51145	69	1	69	1	Table 6.9/Wind energy/biodiversity, "Can be mimimized by careful site selection of wind power facilities": it should be rewritten "significant but can be mimimized by careful site selection of wind power facilities"	Accepted. The text has been revised.	Eric PROUST	European Nuclear Society (ENS)	France
51147	69	1	69	1	Table 6.9/Wind energy/political acceptace, "Opposed by fossil interests": this is not the only driver, another driver of at least equal (and rather of greater) importance for onshore wind energy is the opposition of the local populations/the challenge of social acceptance Marco Sonnberger, Michael Ruddat, Local and socio-political acceptance of wind farms in Germany, Technology in Society, Volume 51, 2017, Pages 56-65, ISSN 0160-791X, https://doi.org/10.1016/j.techsoc.2017.07.005. https://publications.jrc.ec.europa.eu/repository/bitstream/JRC103743/jrc103743_2016.7095_src_en_social%20acceptance%20of%20wind_am%20-%20gf%20final.pdf	Noted. Public acceptance is assessed under the socio-cultural dimension	Eric PROUST	European Nuclear Society (ENS)	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
51149	69	1	69	1	Table 6.9/Technology scalability. 1/ for nuclear, scalability is said to have a negative impact on feasibility (dark brown color) for the alleged reason that "Qualified and skilled labor force could be an issue in case of expansion in nuclear new build". This is blatantly erroneous and MUST be corrected: It is well known, for exemple, that France built a 53 MWe nuclear power plant capacitiy over only 13 years using/converting the workforce of its national utility from coal-fired to nuclear power plant construction and operation. This demonstrates that qualified and skilled labor force is not an issue for the scalability of nuclear. An additional reason (if need be) for a yellow color for nuclear is that switching for fossil to nuclear power would greatly ease the resolution of the problem of the reconversion of the fossil power workforce 2/ Once more, the indication for Solar '"globally scalable" is misleading. Indeed, scalability of solar is limited by the need to compensate for the intermittence of solar through a variety of means whose scalability at present is unknown just because their technology maturity is low (or in some case inexistant) and therfore their economic viability at large scale is presently unknown. All the same, the yellow color is misleading 3/ for Capacity electricity storage, its color indicates scalability has a positive impact on feasibility. This looks like pure whishfull thinking. Scalability at present is unknown just because their technology maturity is low (or in some case inexistant) and therefore their economic viability at large scale is presently unknown	Noted. The text has been revised	Eric PROUST	European Nuclear Society (ENS)	France
51151	69	1	69	1	Table 6.9/Simplicity Stating that Solar and wind are simple technologies is completely misleading. Solar and wind at large scale cannot exist alone and the combinaition of solutions needed to accommodate large share of variable/intermittent renewable in the electricity/energy mix will be extremely complex tecnologically speaking (smart grids, demand side management, hydrid energy sytem management, power to X to power, high temperature electrolysers to produce hydrogen, even affordable batteries for energy storrage will be extremely complex technological objects).	Noted. Storage and energy system integration are assessed as a separate option. Chapther 3 assess the feasibility of different pathways, including a set of options; in this chapter, we assess the feasibility of options separately	Eric PROUST	European Nuclear Society (ENS)	France
51153	69	1	69	1	Table 6.9/Costs in 2030 and long term: 1/ How can Capacity electric storage be yellow (positive impact of cost on feasibility)? This is obviously an error that must be corrected. Developping economically affordable electricity storage technologies deployable at the large scales required is the huge technological challenge. Chances it ill be met by 2050 is betting on hypothetical breakthroughs 2/ Once more, the yellow color for solar is misleading. Only the cost of the solar power facility is considered here while the cost of deplying solar at large scale must incorporate the cost to the electricity system of accommodating its intermittent production. Once more, for the consumer who needs electricity when the sun doesn't shine, the cost of solar is not low, and the cost of solar has not a positie impact on its feasibility	Due to advances in development of storage and solar, the cost of these technologies is decreasing towards the future. As "system integration" is investitaged in a separate column, hence only for solar and storage, the technological perspective of these indicators are considered.	Eric PROUST	European Nuclear Society (ENS)	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
51155	69	1	69	1	Table 6.9/Nuclear energy/political acceptace, "Lack of political acceptable": this global statement is factually wrong and MUST be corrected (as well as the ''coloring"). Political acceptance is quite country-specific: political acceptance is strong in China, Russian Federation, India, the US (during the Trump administration), Canada, UK, Poland, Romania, Bulgaria, Slovakia, Czech Republic, Turkey, Belarus, France, UAE, ... Suggested rephrasing: "Political acceptance is high among those countries who perceive benefits for economy, climate change mitigation and energy security". Modify the color accordingly.	Noted. We assess the feasiblity of options in general. Yet, we do acknowledge that assessment may differ across context, which is indicated under role of context. The text has been revised	Eric PROUST	European Nuclear Society (ENS)	France
51157	69	1	69	1	Table 6.9/Effects on health and wellbeing: The possible differenciation among energy producing technologies is only vis à vis wellbeing since life cycle assessment studies suggest that renewable and nuclear energies have comparable averall impacts on human health which are substantially lower than fossil fuel technologies. So: 1/ It is surprising that Solar be the only energy to be indicated "Globally beneficial'. One would expet a "0" no adverse impact. What are those benefits specific to solar? 2/ The indication "0" no adverse impact for hydropower does not take into account the impact on wellbeing of the population that needs to be displaced/relocated to build large hydropower reservoirs	Noted. The table identifies that there are no adverse effects of solar energy on human health. The statement about hydro power plants is not based on the existing literature.	Eric PROUST	European Nuclear Society (ENS)	France
51159	69	1	69	1	Table 6.9/Nuclear energy/Institutional capacity and governance, "Lenghty licence process, not enough institutions and what they have created is not a sustainable process since everything is falling behind the schedule": 1/ the end of the sentence ("and what they have created is not a sustainable process since everything is falling behind the schedule") is both irrelevant and utterly caricatural: most first-of-a-kind nuclear plant projects may have fallen behind schedule mainly because they were FOAKs. Furthermore, many recent nuclear projects in China, Korea, Russia and elsewhere have been completed on shedule. As stated page 35 line 40 of this chapter, "recent projects in China and Korea have been executed within 6 years". And anyway, what is the relevance with the licencing process? 2/ what is the meaning of "not enough institutions''? What is meant by "institutions"? Which kind of additional institutions would be needed and why/what for? Nuclear energy being, by far, the most regulated energy technology with compliance to regulations drastically controled by relevant regulatory bodies, this statement is incomprehensible and unexplainable. It should be deleted.	Accepted. Text was revised	Eric PROUST	European Nuclear Society (ENS)	France
51161	69	1	69	1	Table 6.9/Nuclear energy/Maturity and technology readiness, "GenIII/IIII+ reactors need to be scaled up more to improve their technology readiness": What may need to be further improved is the readiness of the supply chain in countries that have not built a nuclear plant in more than a decade. Technology readiness of GenIII/IIII+ reactors has been significantly improved owing to FOAK projects as demonstrated with the divergence of AP1000s and EPRs in China	Accepted. Text was revised	Eric PROUST	European Nuclear Society (ENS)	France
51163	69	1	69	1	Table 6.9/Solar and Wind energy/Maturity and technology readiness, "Globally mature". This statement may be formally factual, however it is quite misleading if it is not complemented by something like "however, its production is intermittent (solar) / variable (wind energy) so that, when deployed on a large scale, it needs to be accompanied with large scale electricity/energy storage whose technology maturity is low"	Noted. Storage is assessed as a separate option. Chapther 3 assess the feasibility of different pathways, including a set of options; in this chapter, we assess the feasibility of options separately	Eric PROUST	European Nuclear Society (ENS)	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
51165	69	1	69	1	Table 6.9/Nuclear energy/Employment effect and economic growth, "Depends on size of countries: smaller countries benefit less, big countries benefit more": to be consistent with other energy sources, rephrase as follows: "beneficial, the extent of the benefit is depending on country size: big countries benefitting more than small ones'. Make the cloring consistent with the one of other energy technologies. For reference to emplyment, for instance, A large-scale nuclear power plant will support a peak of around 10,000 jobs during construction (see for instance [1]) [1] The Ten Point Plan for a Green Industrial Revolution, Building back better, supporting green jobs, and accelerating our path to net zero, Her Majesty Government, November 2020, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/936567/10_POINT_PLAN_BOOKLET.pdf	Accepted. Text was revised	Eric PROUST	European Nuclear Society (ENS)	France
51167	69	1	69	1	Table 6.9/Nuclear energy/Employment effect and economic growth, "Also depends on the number of units to be constructed: first two units have minimal effect": the pertinence of this statement is questionnable for a number of reasons: 1/ if it applies (if!), it is only for countries newcomers to nuclear energy 2/ in the context of this report (the mitigation of climate change), it is of little pertinence to consider a newcomer country building just two units and stop there. Consider rephrasing (or deleting), for instance like as follow: "for countries newcomers to nuclear energy, the benefit will be more substantial beyond the constructin of the first two units"	Accepted. Text was revised	Eric PROUST	European Nuclear Society (ENS)	France
51169	69	1	69	1	Table 6.9/Solar energy/Cost in 2030 and long term, "Low and declining" While this statement is formally factual, once more, it is quite misleading if it is not complemented by "however, solar energy production is intermittent so that, when deployed on a significant scale, it needs to be accompanied with deployment of large scale electricity/energy storage whose cost is currently quite high but declining"	Noted. Storage is assessed as a separate option. Chapther 3 assess the feasibility of different pathways, including a set of options; in this chapter, we assess the feasibility of options separately	Eric PROUST	European Nuclear Society (ENS)	France
51171	69	1	69	1	Table 6.9/Wind energy/Cost in 2030 and long term, "Declining" While this statement is formally factual, it is also misleading if it is not complemented by "however, wind energy production is variable so that, when deployed on a large scale, it needs to be accompanied with deployment of large scale electricity/energy storage whose cost is currently quite high but declining"	Noted. Storage is assessed as a separate option. Chapther 3 assess the feasibility of different pathways, including a set of options; in this chapter, we assess the feasibility of options separately	Eric PROUST	European Nuclear Society (ENS)	France
51399	69	1			Consider breaking up Table 6.9 into 4 parts so that it is easier to read.	accepted, we changed the format	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
55793	69	1	69	1	Table 6.9 is extremely complicated and difficult to read. Recommend synthesizing the results into a smaller table and putting the remaining data in an appendix.	accepted, we changed the format	Government of United States of America	U.S. Department of State	United States of America
55795	69	1	69	1	Table 6.9 is totally unreadable.	accepted, we changed the format	Government of United States of America	U.S. Department of State	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
61813	69	1	69	1	Table 6.9. Regarding nuclear, there are several incorrect barriers which need to be corrected and re-evaluated. First, the scenario-results for nuclear seem to constrain nuclear artificially (see https://www.osti.gov/biblio/1163655 where the only scenario NOT limiting nuclear is dominated by nuclear as the cheapest option). This should be corrected by choosing scenarios that do not artificially constrain nuclear expansion to a certain level. Physical potential: Given that nuclear is 100-1000 times more energy dense than other low-carbon technologies, it seems unfair to bring up that "some countries could face limits in finding new sites" as that limit would have been hit much earlier with other low-carbon technologies. Note that nuclear can also be built offshore. Part 1/7	Accepted. The text was revised	Rauli Partanen	Think Atom	Finland
61815	69	1	69	1	Part 2/7. Table 6.9. Land use. As mentioned, land use for nuclear, including final repository, is roughly 100-1000 times smaller than the alternatives. The final repository being built in Finland fits withing the site reserved for the nuclear power station of Olkiluoto and has a minimal land footprint above-ground. Further, the facility will be passively safe (according to the statement of the regulator, STUK: https://www.julkari.fi/bitstream/handle/10024/127133/stuk-b196.pdf?sequence=1&isAllowed=y), and will not have any significant public-health concerns for the above-ground activities in the future (see Posiva's report: https://inis.iaea.org/collection/NCLCollectionStore/_Public/44/091/44091445.pdf. Further, other energy sources such as solar do not have a long-term disposal plan nor regulation that is enforced, yet they contain toxic materials that have no half-life and remain dangerous forever.	Noted	Rauli Partanen	Think Atom	Finland
61817	69	1	69	1	Part 3/7. Table 6.9. Toxic waste, ecotoxicity and eutrophication. The table mentions that long-term solutions are needed, but in reality, these solutions already exist, only the political decision to use them is needed. Further, nuclear waste is the only energy waste that is properly managed and that management funded, while other toxic waste such as that from solar panels can easily end up polluting the environment. It would be prudent to note the fact that nuclear industry is the only industry currently managing its waste comprehensively and responsibly.	Noted. in the revised table toxic waste is indicated as both a barrier and enabler, thus it reflects the sentiment in this comment.	Rauli Partanen	Think Atom	Finland
61819	69	1	69	1	Part 4/7. Table 6.9. Water quantity and quality. While nuclear reactors usually use water for cooling, that water is not "spent", but is returned to the source, only slightly warmer (which difference is controlled by regulations). Nuclear is also extremely suitable for desalinating seawater for human use.	Noted.	Rauli Partanen	Think Atom	Finland
61821	69	1	69	1	Part 5/7. Table 6.9. Costs in 2030 and long term. It should be mentioned that program-build projects of multiple reactors bring down the unit cost very significantly, as happened in the new-comer country project of Barakah, UAE. See Figure 21 in https://es.catapult.org.uk/reports/nuclear-cost-drivers/.	Noted. Costs differ by project / country	Rauli Partanen	Think Atom	Finland
61823	69	1	69	1	Part 6/7. Table 6.9. Political acceptance. There is lack of political acceptance in few select countries, but this is far outnumbered by the around 28 newcomer countries that are constructing or planning to construct nuclear reactors. In sum, the political acceptance is actually rather high for nuclear, globally. See UNECE 2021, https://unece.org/sustainable-energy/publications/nuclear-entry-pathways	Accepted. The text was revised	Rauli Partanen	Think Atom	Finland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
61825	69	1	69	1	Part 7/7. Table 6.9. Institutional capacity and governance, cross-sectoral coordination. The statement that “everything is falling behind the schedule” is simply incorrect. As one can read from (UNECE 2021, https://unece.org/sustainable-energy/publications/nuclear-entry-pathways), “interest in nuclear power is rising and deployment is accelerating” in developing countries that are planning and/or constructing their first nuclear reactors.	Accepted. The text was revised	Rauli Partanen	Think Atom	Finland
64415	69	1	69	1	Table 6.9 needs to be broken up into multiple tables. There is too much information on this graphic to synthesize (or even to read). Could the authors break this table up into a series of tables broken down by sub-categories (e.g., Geophysical, Environmental-Ecological, etc.) and then give each mitigation option a qualitative assessment for each category that could then be rolled up into a single table? Suggest making nuclear power dark brown for toxic waste. There is still no means to eliminate toxic waste and permanent storage solutions are also scarce. I also suggest that nuclear should be dark brown for cost. For coal, local and regional negative economic impacts of phase out are significant and can affect political acceptance. The table absolutely misses the mark with respect to electricity transmission and other forms of energy transport, which have significant environmental, social, financial, and political barriers to implementation. Rolling energy transmission and transport into systems integration obscures this as one of the major challenges of the energy transition. The table also obscures the differences between different forms of energy storage, which is also a major factor in converting the energy system. Energy storage options are at least as diverse as generation options, and really cannot be lumped together.	accepted, we changed the format	Curt Bjurlin	Stantec Consulting	United States of America
65845	69	1	69	1	Table 6.9. Provide the metric that has been used in evaluating the different technologies with respect to each indicator. Without a specified metric, it is impossible to perform the cross comparison in a fair and quantitative manner.	Noted. Different studies use different metrics, so this is not possible. The line of sights provide an overview of the literature assessed	Eero Hirvijoki	Aalto University	Finland
65847	69	1	69	1	Table 6.9. I dispute the given evaluation for nuclear with respect to the indicator "Geophysical/(Physical potential)". There is no explanation why nuclear would be worse than wind, solar, or biomass on the basis of "In case of expansion of nuclear (doubling or tripling of current capacity levels), some countries could face limits in finding new sites for construction." This is an absurd statement considering that nuclear energy has the smallest land footprint of any low-carbon technology and is not subject to wind speed variations or seasonal changes in solar irradiation, nor to the fuel-logistics-related restrictions of biomass power plants. If anything, nuclear should receive a better evaluation than renewables with respect to this indicator.	Accepted. The text was revised	Eero Hirvijoki	Aalto University	Finland
65849	69	1	69	1	Table 6.9. I dispute the given evaluation for nuclear with respect to the indicator Environmental-ecological/(water quantity and quality). If biomass power plants are given a favourable evaluation so should be nuclear: the statement "Needs substantive amount of water for cooling purposes" applies also to biomass plants, as does the concern of thermal pollution. The Drax power station in UK has 2.6GW biomass capacity and uses comparable amounts of water in cooling as nuclear power plants. Furthermore, the Palo Verde nuclear power plant in Arizona, US, the largest in the country, "recycles more than 20 billion gallons of waste water from surrounding municipalities" per year and uses that as coolant. If a biomass plant "Can use waste as a fuel resource", a nuclear power plant can similarly provide sanitation services and direcly contribute to reducing the ecological footprint of cities.	Accepted. The text was revised	Eero Hirvijoki	Aalto University	Finland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
65851	69	1	69	1	Table 6.9. I dispute the given evaluation for nuclear with respect to the indicator "Technological/(technology scalability)". As is well known, nuclear energy has been one of the fastest, if not the fastest clean energy source to scale up with respect to the most important metric, the energy per capita produced (Cao et al., 2016, https://doi.org/10.1126/science.aaf7131). Furthermore, instead of viewing nuclear expansion to depend on labour availability, nuclear energy should be viewed as a driver of higher-education jobs in a similar manner as renewable energy is promoted to create jobs. Consequently, the claim that "Qualified and skilled labor force could be an issue in case of expansion in nuclear new builds" has no validity.	Noted. Skills and quality of nuclear related labor force need some time to be built. In case of rapid expansion, this can be an issue for some newcomer countries.	Eero Hirvijoki	Aalto University	Finland
65853	69	1	69	1	Table 6.9. I dispute the given evaluation for nuclear with respect to the indicator "Economic/(employment effects and economic growth). When measured in jobs per energy produced, nuclear is on par with wind (see Fig. 2 at https://www.world-nuclear.org/getmedia/690859bf-ebe6-43a2-bedd-57ddf47ee3ac/Employment-in-Nuclear-Report-Final.pdf.aspx). For a thorough employment assessment, see (OECD, NEA report no. 7204, https://www.oecd-nea.org/jcms/pl_14912). Additionally, nuclear is the most stable producer of electricity, a factor that is highly regarded in industry.	Accepted. The text was revised	Eero Hirvijoki	Aalto University	Finland
65855	69	1	69	1	Table 6.9. I dispute the given evaluation for nuclear with respect to the indicator "Socio-cultural/(Effects on health and wellbeing). Research shows that nuclear energy is undisputably beneficial for human health (Karecha and Hansen, 2013, https://doi.org/10.1021/es3051197). Nuclear deserves an excellent grade in this category.	Accepted. The text was revised	Eero Hirvijoki	Aalto University	Finland
65857	69	1	69	1	Table 6.9. I dispute the given evaluation for nuclear with respect to the indicator "Institutional/(institutional capacity and governance, cross-sectorial)". The note "Lenghty licence process, not enough institutions and what they have created is not a sustainable process since everything is falling behind the schedule" applies only to the western regulation and institutions. In China and Korea, the average build time of new plants has remained at 6 years, as acknowledged on page 35, line 40. If nuclear is discredited on this basis, then one should address the same issue with respect to wind: in Germany, the deployment time for new onshore wind has increased rapidly due to public opposition and regulation issues.	Accepted. The text was revised	Eero Hirvijoki	Aalto University	Finland
71687	69	1	69	1	Table is very difficult to read and main information is not clear, comparison of generation technologies and energy storage, transmission grids, demand side mitigation and system integration is not done in a consistent way.	accepted, we changed the format	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
75755	69	1	69	1	The indicator Technology Scalability for nuclear is colored in the dark shade of with the comment "Qualified and skilled labor force could be an issue in case of expansion in nuclear new builds". The table is reffered to as a summary. My question is - summary of what, certainly not of data given in the previous sections. This is them first time quallified labor is mentioned in the context of nuclear expansion, no references to support the claim given in the table. Please check the link https://www.iaea.org/topics/nuclear-knowledge-management to see the number of activities IAEA is conducting on issues of nuclear knowledge management.	Noted	Krešimir Trontl	University of Zagreb, Faculty of Electrical Engineering and Computing	Croatia
77387	69	1	69	2	For "biodiversity" it must also be written "Can be minimized by careful site selection and use of modern mitigation measures" for hydropower. The colour should be changes. It is absolutely no scientific evidence that impacts on biodiversity from hydropower cannot be mitigated by measures	Noted. The figure has been reformatted.	Atle Harby	SINTEF Energy Research	Norway

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
85483	69	1	69	1	I understand that a lot of time must have gone into this but if I may give some advice: sometimes a writer has to kill his darlings and I think this is one of these times. I think I'm an expert but with most cells I either understand what is said or what went wrong. Also it tries to aggregate things untill they become meaningless. E.g. the average of all scenarios doesn't mean anything anymore. And the technology readiness of bioenergy, nuclear, wind and solar is highly depending on the flavour of technolgy you are looking at so again you aggregate into meaninglessness. If you really want to keep it, put it somewhere out of the way where it doesn't distract people from other content. I'm not trying to be mean or arrogant but I really think this isn't working. Maybe show it to other people who where not involved in the chapter and ask them honestly what they think.	Noted. The feasibility assessment is generally well received, so we leave it in. We changed the format of the figure so it is more easy to grasp. Important qualification regarding role of context, scale, time are indicated in the table in the Appendix	Auke Hoekstra	Eindhoven University of Technology	Netherlands
64325	69	3	69	3	Waste heat and water source heat should be included as a building space heating energy source option.	Noted. This is assessed in the building chapter	Peter North	Imperial College (part-time PhD student) /Calorem Ltd	United Kingdom (of Great Britain and Northern Ireland)
8927	69		69		This very large sheet is impressive. But can be discussed. In the case of the institutional obstackes to nuclear (bottom of the page), the arguments appear weak. In fact, many countries today (about 30 countries, see the IAEA PRIS base: https://pris.iaea.org/PRIS/CountryStatistics/CountryStatisticsLandingPage.aspx) are building nuclear plants. In these countries, where is the lack of political support? How can they accept such arguments about the weakness of their institutional processes. A sentanec like "Lenghty licence process, not enough institutions and what they have created is not a sustainable process since everything is falling behind the schedule" is very strange. For instance, in Asia, the processes are almost on time. And in Europe the law is always respected, even if postponements need to rewrite documents or to manage new public inquieries.	Accepted. The text was revised	Jean-Guy DEVEZEAUX DE LAVERGNE	Université Paris-Dauphine & Société Française d'Energie Nucléaire	France
9817	69				Table 69 is not legible due to very low font size. Need to include separate tables - one table for each technology	accepted, we changed the format	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
9819	69				Need to include the definition of LoA = 4,5; LoC = 4,5 etc.	accepted, we revised the tekst to clarify this	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
12209	69		69		In figure 6.9, we disagree with the assessment of nuclear agains technology simplicity and scalability as dark brown. Skilled labour force and know how transfer might indeed be an issue in the framework of expansion of the nuclear capacity, but nuclear has been around for 50 years during which time it formed several generations of specialists and given plans for new nuclear build and government support, more young professionals can be attracted to this field. There are diverse international organizations dealing with nuclear training and education in order to preserve and expand know how: WNN, ENEN, SNETP etc. We also disagree with the evaluation against public opinion criteria. Please see the Comparative Analysis of Public Attitudes toward Nuclear Power Energy across 27 European Countries by Applying the Multilevel Model, 2018, by Jaesun Wang and Seoyong Kim to understand that public support for nucler in Europe has either increased or stayed the same and some countries such as Japan which moved away from nuclear are restarting their nuclear programs. As mentioned correctly in the IPCC report, public acceptance is highly dependent on the maturity of the institutions, the independence of the regulatory body and the level of general information and education about nuclear. We also disagree with the evaluation under Institutional criteria. Nuclear energy is at times a political decision but its deployment depends on independent factual based analysis and screening criteria. Also, we believe that institutitions in nuclear are quite mature and able to handle licensing processes and cooperation across boarder. Licensing for FOAK is naturally a lenghtly process given the implication and mandatory analysis. It should be a strong point of nuclear not a weak one.	Noted. The technology itself is complex although mature.	Lavinia Rizea	SN Nuclearelectrica SA	Romania
15543	69				The line "technological scalability" for nuclear power is marked as negative due to the possible shortage of qualified personnel. It is not correct and should be changed because the existing practice of construction of nuclear power plants in the so-called newcomer countries shows that such personnel are prepared in a timely manner. The same corrections need to be done with the line "public acceptance" because in those countries where the construction of nuclear power plants is supposed to be constructed generally positive. Nuclear power provides a guaranteed supply of energy, jobsand employee safety. (Nuclear Power and Sustainable Development, IAEA, Vienna 2016.)	Noted. The practice in some newcomer countries shows exactly the opposite: the power plant is there but for the lack of labor force it does not start.	Vladimir Kucinov	National Research Nuclear University "MEPHI" (Moslow Enginiring Physical Institute)	Russian Federation
17913	69				Table is unreadable	accepted, we changed the format	Robert Brecha	Climate Analytics	Germany
61219	69		69		Table 6.9 is not clear.	accepted, we changed the format	Jianguo WU	chinese research academy of environmental sciences	China
63663	69		69		Table 6.9 - for the environmental indicator "water use" - the entry for bioenergy is repeated from above and the entry for biodiversity is relevant to water use - however, not all biomass has a very high water use, in fact most biomass used for energy currently does not (e.g. forest and agriculture residues). High water use may be a concern for plantations but fast growing energy crops can also be strategically planted to filter water and improve quality while using less water than other agriculture crops. In general the impacts stated seem to be most relevant to biofuels and purpose grown crops while other more commmon sources/uses of biomass are ignored.	The feasibility table has been corrected and updated to reflect that not all biomass requires high water use	Government of Canada	Environment and Climate Change Canada	Canada
74853	69		69		Contents of Table 6.9 are microscopic and not easy to read unless magnified.	Accepted, we changed the format	Government of Kenya	Kenya Meteorological Service	Kenya

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
77241	69				The choice of the judgments seems arbitrary, not always reflecting the actual situation and/or a global perspective. E.g. - political acceptance of nuclear is highly not uniform, with countries strongly against and others strongly in favor; - technical options exist to avoid any need for cooling water: it is not commonly adopted because introduces some additional costs, but is available (and already in use in some cases); - Gen III reactors are mature, as they are commercial; the statement is only valid for Gen III+ reactors; - "not limited by materials" for PV on geophysical resources seems to ignore the need for rare earths, or (if referred to alternative technologies which don't require such materials) is not coherent with other metrics (e.g., technology readiness); - the "not enough institutions and what they have created is not a sustainable process since everything is falling behind the schedule" is not correct (institutions are adequate), and biased (not all projects fall behind schedule, and is not clear in any case how this matches with being not sustainable).	Accepted. The text was revised	Giacomo Grasso	ENEA	Italy
78515	69		69		Physical potential for nuclear should be yellow. Small footprint of nuclear makes it easy to have multiple units on one site, so even doubling or tripling current capacaity is not a problem form physical potential. In addition SMR reactors are designed to replace coal power plants and can be build on former coal-plant sites, Nuclear has smallest land requirements.It is possible to build nuclear reactors (especiali SMR) on coal power plant sites. Technological Scalability for nuclear shuld be light brown. Nuclear is scalable from 100 MW to 1600 MW. Effects on health and wellbeing for nuclear should be yelow. Nuclear pworides high quality jobs. Good educatoion and wellbeing. All labor force is well payed and high quality. Water quantitiy and quality for bioenergy shuld be brown or light brown as other thermal technologies. Also nuclear can use waste water for cooling.	Accepted. The text was revised	Tomaž Žagar	Faculty for Energy Technology, University of Maribor	Slovenia
78517	69		69		Low costs of wind and solar: yes - without storage and integration. Storage and integration costs in the columns on the right hand side of the table are marked as low (brightest color). Which is not true. Simple scalling of the current costs of Tesla batteries show that these are very expensive options. Significant electric grid upgrades are costly too.	Noted. Storage is assessed as a separate option. Chapther 3 assess the feasibility of different pathways, including a set of options; in this chapter, we assess the feasibility of options separately	Tomaž Žagar	Faculty for Energy Technology, University of Maribor	Slovenia
78519	69		69		scalability of nuclear is disputed because of the need for qualified and skilled labor force. What kind of future is foreseen: large numbers of poorly skilled workers intalling and maintaining PV and wind turbines, or much smaller number of highly skilled staff? I would not punish nuclear because of that. This remark should be deleted and color changed to brightest.	Noted	Tomaž Žagar	Faculty for Energy Technology, University of Maribor	Slovenia
78521	69		69		"Lack of political acceptance" for nuclear - that depends on the country. There are also countries where other sources are not acceptable. So the color should not be dark but intermediate.	Noted. We assess the feasiblity of options in general. Yet, we do acknowledge that assessment may differ across context, which is indicated under role of context	Tomaž Žagar	Faculty for Energy Technology, University of Maribor	Slovenia

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
78523	69		69		nuclear institutional capability: "Lenghty licence process, not enough institutions and what they have created is not a sustainable process since everything is falling behind the schedule". Even if falling behind the schedule is true, it is impossible to deny the fact, that in two similar countries, France and Germany, France managed to decarbonize their electricity with nuclear in two decades, while Germany three decades later did a rather poor job with wind and solar in a similar period. So the color of this criteria depends on the country and should not be dark.	Accepted. The text was revised	Tomaž Žagar	Faculty for Energy Technology, University of Maribor	Slovenia
48325	70	0	70	0	The chart is not legible	Noted. The whole table has been re-structured.	Susana Hancock	University of Oxford	United States of America
64327	70	0			This chapter does not highlight local waste heat and environment energy from the ground and water as a sources of energy for building space heating. The positive environmental impact includes improved air quality (by displacing the use of combustion technologies),	Rejected. outside the scope of the section.	Peter North	Imperial College (part-time PhD student) /Calorem Ltd	United Kingdom (of Great Britain and Northern Ireland)
47653	70	1	78	43	This section can benefit from a recent publication (Gernaat et al.) which uses the the ISIMIP projections for different RCPs and runs them through and IAM in order to determine (i) Changes in the supply of different forms of renewable energy, and (ii) How these affect energy system projections. The method uses climate projections from a number of climate models in order to investigate the robustness of the results. https://www.nature.com/articles/s41558-020-00949-9	Taken into account. The noted reference was not available at the time of the SOD.	Vassilis Daioglou	Utrecht University	Netherlands
55797	70	1	78	1	The section must be expanded to cover all energy, not just electricity.	Partly taken into account. The section already covers other forms of energy, e.g. bioenergy, but scientific evidence/publications are limited.	Government of United States of America	U.S. Department of State	United States of America
85485	70	1	78	43	As a geek I found this a really interesting paragraph but then I asked myself: what am I going to do different now that I know all this? And the answer for me is: nothing. So I would advocate keeping the paragraph but make it into one big textbox with differently colored pages and no subparagaphs in the table of contents. It should be easy for people to peruse it but it's not part of the overall story. (Story as I see it: Ploblem!>Options>Putting it all together>Action!)	Taken into account. We have revised the first section.	Auke Hoekstra	Eindhoven University of Technology	Netherlands
2873	70	2	70	13	Resilience has become a very relevant issue in energy planning, given the increase in natural and man-made disasters and the need to secure crucial services and critical infrastructure, such as healthcare facilities, in the event of an energy service interruption. Resilience will become a more important factor as extreme events caused by the planetary climate crisis become more frequent. Resilient sustainable energy systems are necessary to ensure vital energy services are provided under a wide range of circumstances, helping to protect lives and critical infrastructure and support vulnerable communities. This should be acknowledged in the text.	Taken into account. A new box on Energy Resilience is now part of this section	Leonardo Barreto	Head of center "EU&International"	Austria
37727	70	2	70	2	This section is about the current and future energy systems which form the basis for climate change. Nuclear is missing. Any explanation for leaving out nuclear.	Taken into account. Climate change impacts on nuclear power are presented in the section 6.5.1.6 "Thermal power plants". The section has been expanded. More generally, nuclear power is presented in section 6.4.2.4 "Nuclear Energy".	Ravi B Grover	Homi Bhabha National Institute	India
48321	70	2	70	2	How do we know about future energy systems?	Noted.	Susana Hancock	University of Oxford	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
33063	70	7	70	7	the impact of climate change is not only on vulnerability of power systems but on all "energy systems"	Taken into account. The first paragraph of this section has been extend to include as much as possible all possible impacts of climate on energy sytems.	Yashar Hajimolana	University of Twente	Netherlands
51315	70	10	70	11	I strongly recommend that after the end of the sentence inherent in Line 10, the following sentence be added: Electricity consumption of a country is one of the main parameters to measure the degree of its development (Seljom et al., 2011), as it is directly connected to the degree of industrialization of the country. A possible and expressive loss in electricity production capacity could bring serious social and economic risks to the country. REFERENCE: Seljom, P., Rosenberg, E., Fidje, A., Haugen, J. E., Meir, M., Rekstad, J., & Jarlset, T. (2011). Modelling the effects of climate change on the energy system—A case study of Norway. Energy Policy, 39, 7310–7321. https://doi.org/10.1016/j.enpol.2011.08.054	Taken into account. The relevant paragraph has been modified to mention social and economic risks.	Government of Brazil	Ministry of Foreign Affairs of Brazil	Brazil
43889	70	11	70	13	The explanation provided by this sentence seem to be in contrast with what the title is perceived to be. If this sentence is to be followed, then I suggest the title of this section must be replaced. A suggestion would be "Climate Change Impact in the Mitigation Potential of Energy Systems". By including "mitigation potential", this could prepare the readers that this section will mostly cover the impact of climate change on renewable energy resources and systems.	Taken into account. The introductory paragraph to the section has been rewritten	Vince Davidson Pacañot	University of the Philippines Diliman	Philippines
48323	70	11	70	13	This sentence is really not clear	Taken into account. The introductory paragraph to the section has been rewritten	Susana Hancock	University of Oxford	United States of America
85445	70	11	70	13	The title of this section is "Climate Change Impacts on the Energy System" but "The focus of this section is not on how climate affects the energy system".	Taken into account. The introductory paragraph to the section has been rewritten	Auke Hoekstra	Eindhoven University of Technology	Netherlands
85447	70	11	70	13	"Climate change impacts on bioenergy potentials are complex and more uncertain because of uncertainties associated with…" I would personally add "the way humans act to mitigate these problems". (Just saw a documentary how China is reversing desertification of the Loess plateau by measures like limiting overgrazing and adding plateaus that limit runoff.)	Accepted. The sentence has been expanded to add "and the political response to climate mitigation".	Auke Hoekstra	Eindhoven University of Technology	Netherlands
85449	70	11	70	13	This is an extremely important paragraph that should introduce the reader to the 8 pages of paragraph 6.5. It could be rewritten to perform that function better.	Taken into account. The introductory paragraph to the section has been rewritten	Auke Hoekstra	Eindhoven University of Technology	Netherlands
8889	70	13	70	14	Figure 6-19: in the wake of the Texas power outages--can the impacts to thermal, wind, and solar of a cold spell/snow & ice be plausibly considered "none/very little impact"?	Taken into account. The introductory paragraph to the section has been rewritten. In addition, a new box on energy resience is now part of the section.	Seth Dunn	ServiceMax	United States of America
15545	70	13	70	18	It should be specified that the category "thermal power plants" means nuclear power and solar thermal power stations.	Taken into account.The row on table 6.19 has been expanded.	Vladimir Kucinov	National Research Nuclear University "MEPHI" (Moslow Enginiring Physical Institute)	Russian Federation
64417	70	13	70	14	Figure 6.19. Considering recent events in Texas, suggest revisiting the effect of extreme cold on thermal power plants. Also, I would argue that coastal flooding impact on power systems is a quantified direct impact (e.g, superstorm sandy, etc.). Same goes for sea level rise, with many power utilities hardening coastal systems. This is well described in section 6.5.3, flooding, but should also be reflected in the table.	Please see response to comment 8889.	Curt Bjurlin	Stantec Consulting	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
74209	70	13	70	18	As nuclear is currently 35% of the world's carbon free energy, its absence from this figure (6.19) is notable.	Taken into account.The row on table 6.19 has been expanded.	Jeffrey Merrifield	Pillsbury Law Firm	United States of America
76411	70	13	70	14	Regarding figure 6.19. Nuclear energy thermal plants have been shown across the globe to free from the impacts of cold conditions and floods in the USA. Hot weather if dependant on inland water resources does present a vulnerability however this does not occur with once through sea water cooling. Newer small nuclear power plants are being designed with hybrid cooling systems that reduce water consumption from fresh water resources by around 70%. Drought does not have any impact on plants located in coastal ares .	Noted. But such a lengthly explanation is outside the scope of the section.	Robert Parker	Nuclear for Climate Australia	Australia
12207	70	14	70	14	In figure 6.19 nuclear power is not included. However in chapter 6.5.1.6 nucler power is associated with thermal energy which is not relevant for the comparrison since nuclear has different needs and uses different resources than thermal power plants	Taken into account.The row on table 6.19 has been expanded.	Lavinia Rizea	SN Nuclearelectrica SA	Romania
15255	70	14	70	14	Cold spell and temperature variability may have an impact on the operation of onshore wind farms. It is suggested to add 2 gray blocks in the second row "design and Operation (onshore)" of "Wind energy", and in the first column "cold spell " and "temperature variability" in Figure 6.19.	Noted. The table has been re-structured.	Government of China	China Meteorological Administration	China
17417	70	14	70	14	Table 6.19: Heat and cold affect efficiency and vulnerability of thermal power plants but does not affect solar CSP, which works on similar principles. How can one explain that?	Noted. The table has been re-structured.	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
17419	70	14	70	14	Table 6.19: Strange claim: snow cover does not affect PV.	Noted. The table has been re-structured.	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
21057	70	15	70	15	(editorial comment) this figure will gain te be enlarged or to have its characters enlarged.	Accepted. The figure has been converted to a table and redrawn.	Government of France	Ministère de la Transition écologique et solidaire	France
12213	70	17	70	19	While the affirmation that heating water sources affect the efficiency of NPPs, there are technical solutions to overcome this problem and many NPPs use them: first, the cooling capacity of the reactor systems may be recalculated, secondly the cooling systems may be altered so that bottlenecks are removed, thirdly, redesigning cooling systems addresses the issue by increasing the cooling capacity. There are solutions and their implementation depends on a cost-benefit analysis. This should be reflected in the IPCC report since nuclear is nore resilient than the report portrays.	Noted. Unfortunately due to space limitations the issue cannot be included.	Lavinia Rizea	SN Nuclearelectrica SA	Romania
17421	70	19	70	19	Climate change will not affect renewable potentials. How about renewable plants?	Noted. That topic is part of the rest of the section.	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
64419	70	19	70	28	As a secondary impact, spending money to adapt to climate change (e.g, harden energy systems), may decrease the capital available to implement mitigation by causing bankruptcies, increased taxes to fund recovery, etc. Question: is there literature addressing the potential for runaway costs of adaptation affecting ability to invest in mitigation? Also see section 6.5.3	Rejected. Out of the scope of this section	Curt Bjurlin	Stantec Consulting	United States of America
78637	70	20	70	28	higher shares of VRE (PV, wind) reduce the reliance on thermal power plants and the associated water demand for cooling as clearly concluded by Lohrmann et al. (https://www.nature.com/articles/s41560-019-0501-4)	Rejected. Out of the scope of this section	Christian Breyer	LUT University	Finland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
15547	70	21	70	21	It should be specified that the category "thermal power plants" means nuclear power and solar thermal power stations.	Accepted. The table has been restructured to explicity include nuclear power in thermal power plants.	Vladimir Kucinov	National Research Nuclear University "MEPHI" (Moslow Enginiring Physical Institute)	Russian Federation
48327	70	21	70	24	A single sentence explaining why global and regional differences exist (this is covered on p72, ln8-14 but begging question here).	Accepted. A followup explanation has been added "because the response of the climate system is regionally complex"	Susana Hancock	University of Oxford	United States of America
5379	70	22	70	22	Add to the list : coal; fuel gas, nuclear which are neither affected, no more than renewables that you are citing.	Accepted. The aditional energy sources have been added	Michel SIMON	Retraité/ Pdt d'association	France
10649	70	23	70	23	the significance of the "RE" acronym is unknown	Accepted. The acronym definition has been added.	Philippe Waldteufel	CNRS	France
28629	70	27	70	27	I suggest adding the word "Potential" to the start of this sentence, because water use with CCS can be managed, see references Giannaris, S. et al (2020). “Implementing a second generation CCS facility on a coal fired power station”, Greenhouse Gases: Science and Technology, 10(3), 506-518; Magneschi et al (2017) "The Impact of CO2 Capture on Water Requirements of Power Plants", GHGT-13, Energy Procedia 114 6333-6347 ; IEAGHG (2020) “Understanding the cost of reducing water usage in coal and gas fired power plants with CCS”, IEAGHG 2020-09; IEAGHG (2011) "Evaluation and Analysis of Water Usage of Power Plants with CO2 Capture" IEAGHG 2010/05; IEAGHG (2020) "CCS and the Sustainable Development Goals", IEAGHG 2020-14; Mikunda et al (2020) "CCS and the Sustainable Development Goals", International Journal of Greenhouse Gas Control (submitted 17 Nov 2020)	Accepted. The text has been revised	Tim Dixon	IEAGHG	United Kingdom (of Great Britain and Northern Ireland)
86593	70		127		Sections 6.6 and 6.7 seem to be very much out of step with the majority of the chapter 6 and other chapters (2) and I suspect the problem lies with the integrated assessment models. Several times in chapter 6 it is noted that the relative costs of various technologies are key to the likely energy mix for a net zero system and the pace of mitigation, and the acceptabity of mitigation efforts. However, the modelled outputs of 6.6 and 6.7 do not appear to reflect this insight. The costs of renewables in these IAMs have been shown to be out-of-date (Krey et al. 2019) and a poor reflection of actual trends (Ives et al. 2021 (in prep) and Farmer and Lafond, 2016). Most (if not all) of the 1.5/2 degree scenarios have large deployments of CCS technologies, and relatively modest deployment of renewables (40% of electrified energy by 2050 which is only 40% of total final energy), which does not at all reflect actual trends, as shown in Figure 2.30, and discussed extensively in the remaining sections of chapter 6. I believe the way the IAM data is presented is misleading. The costs shown in Figure 6.31 are completely dependent on this use of out-of-date data and innapropriate trends. If the inability to update the IAMs with better cost data, or embodying non-linear dynamics in technology adoption, is the source of the problem then their results should not be used in discussions around future energy mix and costs, as they are in sections 6.6 and 6.7, because these models are not fit for this purpose.	Out of place	Matthew Ives	University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
61223	71	1	78	42	Only the impact of climate change on the energy system has been assessed, and no adaptation countermeasures have been assessed. It is recommended to increase the assessment of adaptation countermeasures	Rejected. Out of the scope of this section	Jianguo WU	chinese research academy of environmental sciences	China

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
62009	71	1	72	27	This chapter "6.5.1.1 Hydropower" deals with the effects of climate change on hydropower. One more low key effect is the need of increased use of hydropower to regulate the variable energy production. See e.g. Wang et al., 2018 (Weijia Yang, Per Norrlund, Linn Saarinen, Adam Witt, Brennan Smith, Jiandong Yang & Urban Lundin, 208, Burden on hydropower units for short-term balancing of renewable power systems. Nature Communications volume 9, Article number: 2633). In many coutries e.g. Brazil the hydropower genertation is by nature base generation. As increasing renewable places more demands on balancing electricity the balancing burned falls more heavily on hydropower. Environmentally it is not the same if we run our river at 100% throughout the day compared to running it 300% for 8 hours and letting the river dry for 16 hours. Increasing variablility naturally has limits placed by environmental limits which are unique to each location. Suggest adding a statement e.g. "Another more subtle effect is the need of increased use of existing hydropower to regulate the growing variable energy production. See e.g. Wang et al., 2018. Having hydropower units to vary their production in wider range or more frequently requires additional investments and will have location specific effects of the ecosystems the hydropower units operate which will be needed to mitigate. "	Taken into account. Mention to the regulatory aspect of hydro on the future energy mix has been included on section 6.4.2.3	Esa Vakkilainen	LUT University, Lappeenranta	Finland
73985	71	8	71	9	replace "technical elements" by "electromechanical elements"	Accepted. The sentence has been changed.	Heleno Miguel	Lawrence Berkeley National Laboratory	United States of America
52239	71	11	71	11	"Structure security" should be structural security and it is not clear what this term means.	Accepted. The sentense has been modified for clarification	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
18253	71	19	71	22	(Section 6.5.1.1) Glacial melt is temporary, lasting only until the glaciers have disappeared. Suggest including the fact that the increase in water availability associated with glacial melt is temporary.	Taken into account. The temporary aspect is included in the sentence	Government of United Kingdom (of Great Britain and Northern Ireland)	Department for Business, Energy & Industrial Strategy	United Kingdom (of Great Britain and Northern Ireland)
29915	71	19	71	22	Please consider to also include that higher temperature also leads to increased evaporation/increased water consumption/conflicting water demands etc., seasonal draughts and less available runoff/inflow to the HP reservoirs. Bakken et al (2016) - https://www.mdpi.com/1996-1073/9/3/191	Accepted. Conflicting water demands is included in the text.	Government of Norway	Norwegian Environment Agency	Norway
29917	71	19	70	22	Please consider to add " The combined effect of climate change and extended irrigation withdrawals will overall lead to reduced runoff in many rivers. The changes might be dramatic in semiarid areas, reducing the water available for hydropower production. The presence of the reservoirs will lead to extended water use/losses due to the provision of regulated flow, enabling larger irrigation withdrawals and increasing the evaporative losses from the reservoir surfaces (Bakken et al, 2016 - https://www.mdpi.com/1996-1073/9/3/191).	Taken into account. Mention to water competing activities is made on section 6.4.2.3	Government of Norway	Norwegian Environment Agency	Norway
55799	71	19	71	22	This sentence mentions that an increase in glacial melting due to higher temperatures will increase water availability for hydropower. However, that positive impact for hydropower would only be temporary, correct? What happens when the glaciers disappear? How much hydropower relies on glacial melt and is in a position to no longer be viable if that source of water is lost? Will increased rainfall offset the lost water from glaciers?	Taken into account. The temporary aspect is included in the sentence	Government of United States of America	U.S. Department of State	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
42985	71	22	71	23	Are there new comparable figures available from AR6? Lateral hydrological flows and streamflow generation in the previous generation of LSS were relatively crude (Davison et al, 2014) and do not result in reliable streamflow predictions.	Rejected. There are no AR6 results on the impacts of climate change on hydropower that we are aware of.	Kurt Kornelsen	Ontario Power Generation	Canada
43599	71	22	71	22	Replace "fulling" with "fully"	Accepted. The text has been revised	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy
15257	71	23	71	23	In Figure 6.20, the East Section of China-India Border is wrongly drawn and the Dotted Line of South China Sea, Nanhai Zhudao, Diaoyu Dao and its affiliated islands of China are missing. It is suggested to use a color block map, delete the national boundary lines, and mark the island points. As for the East Section of China-India Border, it is suggested to use a color block map or mark the line as claimed by the two sides in the disputed area.	Taken into account. We have asked the authors for a new version of the figure.	Government of China	China Meteorological Administration	China
10651	71	24	71	24	Is showing percentages on this figure 6.20 the most appropriate choice? For regions with very small hydropower potential, a loss of 60% is not very meaningful.	Rejected. The figure used is from Van Vliet et al. 2016c.	Philippe Waldteufel	CNRS	France
61221	71		71		Figure 6.20 The borders of the country are blurred, which is easy to cause controversy. Remove the borders	Taken into account. We have asked the authors for a new version of the figure.	Jianguo WU	chinese research academy of environmental sciences	China
5381	72	3	72	30	add after "Climate change", "when used to replaced carbon sources"	Rejected. Do not understand the suggestion.	Michel SIMON	Retraité/ Pdt d'association	France
4127	72	8	72	10	"Nonetheless, the analyses are consistent in demonstrating that globally, the impact of climate change on hydropower is small; however regionally they are variable both positively and negatively." Although seemingly correct, I am not quite comfortable with this exposition, because the appearant "globally small" impact is the result of large positive/negative regional impacts cancelling each other. Because hydropower is used to generate electricity that can not be transmitted over long distances (unlike, say, crude oil), it can also be argued that the positive/negative impacts in many regions across the globe could collectively amount to a "significant" global impact, even if they cancel each other.	Taken into account. An analysis about the regional impacts is presented on the same section.	Tatsuki Ueda	National Agriculture and Food Research Organization	Japan
42987	72	15	72	27	This section does not discuss the impacts of seasonality of streamflow under a changing climate. Increases in average or annual streamflow do not necessarily result in greater hydropower production. Most studies show increasing winter flows at a time reservoirs are already drawing down or during spring/fall when there is typically more flow in the Northern Hemisphere. This freshet season is typically beyond plant capacity and there is no market for the energy. Summer periods in many Northern Latitudes are expected to be drier, when energy demand is higher.	Reject. Due to limitation in space, seasonal impacts were not discussed.	Kurt Kornelsen	Ontario Power Generation	Canada
42989	72	15	72	15	It could be noted that upgrades to take advantage of 5-20% flow may have challenging economics.	Accepted. The word costly was included in " … changes the timing of snow and ice melt that may require costly upgrading in storage capacity and adaptation of the hydropower plant management for fully exploiting the increase in water availability."	Kurt Kornelsen	Ontario Power Generation	Canada

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
15105	72	25	72	27	The literature in section 6.5.1.1 lacks the research results of Chinese scholars. Lines 25-27 think that the research conclusions of the impact of climate change on hydropower generation in China are inconsistent. It is suggested to add a viewpoint that climate change will increase the hydropower potential in Southwest China. References include: 1）LIU X C, TANG Q H, VOISIN N, et al. Projected impacts of climate change on hydropower potential in China. Hydrology and Earth System Sciences, 2016, 20(8): 3343-3359. 2）ZHONG R, ZHAO T, HE Y, et al. Hydropower change of the water tower of Asia in 21st century: A case of the Lancang River hydropower base, upper Mekong. Energy, 2019, 179: 685-696. 3）Wang, T., Zhao, Y., Xu, C. et al. Atmospheric dynamic constraints on Tibetan Plateau freshwater under Paris climate targets. Nat. Clim. Chang. (2021). https://doi.org/10.1038/s41558-020-00974-8	Taken into account. References were included.	Guoquan HU	National Climate Center of China Meteorological Adminstration	China
52243	72	25	72	27	Missing references.	Taken into account. References were included.	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
51319	72	27	72	27	After the end of the Line 27, it should be added: The most recent studies, however, point out that the planning of expansion of electricity sector considers the impacts of the climate change, especially in countries have an expressive hydraulic generation (like, Brasil, China or Norway), incorporating scenarios regarding the climatic variations and the losses in hydroelectricity production capacity, attributed to the hydro-climatic factor.	Rejected. Out of the scope of this section	Government of Brazil	Ministry of Foreign Affairs of Brazil	Brazil
15107	72	29	72	32	The overall conclusion is that climate change has no significant impact on wind energy resources. This conclusion is not consistent with the facts, the observation data show that the global wind speed is on a downward trend (Chang et al, 2021); the interannual fluctuation of wind energy is large, and climate change increases the interannual fluctuation of wind energy, which has a great impact on wind energy output. In addition, the credibility of the conclusion is high confidence, and it is suggested to change it to medium confidence. reference: Chang, R., C.Xiao, Y.Wang, F.Yang, C. Liu, 2021: Growing Challenge of Climate Service for Wind Energy Deployment Under Global Warming. Journal of Global Energy Interconnection, 4(1). (In Chinese). DOI：10.19705/j.cnki.issn2096-5125.2021.01.002	Taken into account. The issue of wind and solar intermitency is discussed in 6.4.2.1 and 6.4.2.2	Guoquan HU	National Climate Center of China Meteorological Adminstration	China
73987	72	29	72	32	There is an important impact of climate change on the long-term uncertainty of wind that might be important to mention. For example, regarding the geographical availability of the wind (e.g. N. Berg, A. Hall, S. B. Capps, M. Hughes, El Niño-Southern Oscillation impacts on winter winds over Southern California)	Taken into account. The issue of wind intermitency is discussed in 6.4.2.2	Heleno Miguel	Lawrence Berkeley National Laboratory	United States of America
10653	72	42	72	44	On p42, probably insert "of" after "agreement"; on p44 specify what "is lower than"	Accepted. The text has been revised	Philippe Waldteufel	CNRS	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
28633	73	3	73	3	Also extreme cold in winter storms causes wind turbines to stop operating, as seen in winter storms in Feb 2021 in N.America, see https://www.nrcan.gc.ca/energy/energy-sources-distribution/renewables/wind-energy/wind-energy-cold-climates/7321	Noted. Yes this issue is noted in table 6.19 and in the new box on energy resience.	Tim Dixon	IEAGHG	United Kingdom (of Great Britain and Northern Ireland)
8865	73	13	73	15	The statement about homogeneity of wind speed over large areas is from Wohland et al., 2017 (already in bibliography) and not in Schlott et al., 2018. In fact, the paper by Schlott in Section 1 writes "They find more homogeneous wind conditions over Europe resulting in intensified simultaneous generation shortfalls"referring to the paper by Wohland et al. Then I'd suggest changing this reference.	Taken into account. The reference has been changed to (Wohland et al. 2017)	Matteo De Felice	European Commission	Netherlands
71689	73	29	73	29	Solar Energy refers only to solar PV, but nothing about solar thermal, which also has a considerable impact.	Rejected. We prefer to base our analysis from the original articles rather than a scoping review. We have found no references in the literature.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
5383	73	31	73	31	add after "Climate change", "when used to replaced carbon sources"	Rejected. The suggestion is not understood.	Michel SIMON	Retraité/ Pdt d'association	France
10655	73	31	73	37	One sentence repeats almost exactly the previous one. Possibly the sentence lines 31-34 should be deleted.	Accepted. The text has been revised	Philippe Waldteufel	CNRS	France
17525	73	31	73	37	duplicated sentence	Accepted. The text has been revised	Alaa Al Khourdajie	IPCC	United Kingdom (of Great Britain and Northern Ireland)
48329	73	31	73	31	Clarify "downward"	Accepted. The text has been revised	Susana Hancock	University of Oxford	United States of America
21059	73	35	73	35	There is no consensus that climate change will lead to an increase of downward solar radiation. Here , it seems assumed that it will be so. Please could you explain why.	Rejected. The text explicity mentions "in some models and scenarios", so no consensus is assumed.	Government of France	Ministère de la Transition écologique et solidaire	France
78639	73	35	73	48	the review study of Emodi et al. (https://www.sciencedirect.com/science/article/pii/S0048969719318297), which has shown in a highly comprehensive way the impact, also in detail for solar energy, but also for other resources - providing a very good overview on literature	Rejected. We prefer to base our analysis from the original articles rather than a scoping review.	Christian Breyer	LUT University	Finland
74881	73	39	73	41	While there is expected improvement in solar PV performance due to climate change. Studies reveal that large solar farm would exaberate rise in global temperature due to solar PV heat island (PVHI) with counter effect to ambient temperatures and heat waves. Barron-Gafford, G., Minor, R., Brooks, A., Pavao-Zuckerman, M., & Cronin, A. (2016). The Photovoltaic Heat Island Effect: Larger solar power plants increase local temperatures (Open access: http://www.nature.com/articles/srep35070). Scientific Reports, 6, 35070. https://doi.org/10.1038/srep35070	Taken into account. The issue of the impact of solar farms on the environment is a focus of Box 6.4	Government of Kenya	Kenya Meteorological Service	Kenya
21061	73	43	73	43	About "[...] reflect change in pollution levels [...]": please consider that it is not realy an impact of cimate cange, but the effect of reduced emissions of aerosols (not GHG).	Rejected. The climate model scenarios include changes in aerosol concentrations as well as greenhouse gases.	Government of France	Ministère de la Transition écologique et solidaire	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
65859	73	44	73	48	The statement "In contrast to PV, CSP output increases with increasing temperatures" does not have sufficient proof. The cited paper (Wild et al., 2017, https://doi.org/10.1063/1.4975562) is a reiteration of an earlier paper (Crook et al., 2011, https://doi.org/10.1039/C1EE01495A) where the thermal efficiency analysis of a CSP plant includes only the heat flux into the working fluid. The actual power plant component is ignored. As CSP plants are thermal plants, it is inconsisted to simultaneously claim that thermal plants suffer from ambient temperature increase due to the reduced condenser efficiency but thermal CSP plants would be able to circumvent this effect. Furthermore, as CSP plants are typically operated in far more water restrictive areas than, e.g., nuclear plants, dry-cooling techniques, that are more prone to the ambient temperature variation than wet-cooling techniques, are more likely considered. Please fix this inconsistency.	Accepted. We have found no evidence of increased in CSP efficeincy with temperature. The text has been revised accordingly.	Eero Hirvijoki	Aalto University	Finland
21063	73	47	73	48	Is that in absolute or in relative? Currently, CSP is very small compared to PV, so that even a strong relative change has little impact	Accepted. The text has been clarified "The estimated future production changes by CSP are a factor of 4 larger than those estimated changes to the solar PV production"	Government of France	Ministère de la Transition écologique et solidaire	France
52245	73	47	73	48	Not sure what metric is 4 times larger. Sentence is unclear.	Accepted. The text has been clarified "The estimated future production changes by CSP are a factor of 4 larger than those estimated changes to the solar PV production"	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
21065	74	2	74	2	About "[…] trends in surface solar radiation of –0.60 W/m2 per decade […]": the previous paragraph starts with the statement that solar radiation will increase. So it seems this is not true eveywhere.	Accepted. The last two paragraphs have been rewritten.	Government of France	Ministère de la Transition écologique et solidaire	France
4185	74	6	74	7	It should be noted that "The PV sector may be affected by a decrease in solar radiation due to increasing cloud cover, influenced by rising, warm air currents associated with current and project warming global temperatures."	Rejected. The mechanisms that lead to changes in cloud cover are very complex and outside the scope of this section.	Neil M. Mulchan	Adventure Physics, LLC	United States of America
21067	74	8	74	8	Generally higher temperatures would likely increase the fuel consumption in oil-based people transportation, by decreasing the efficiency of internal combustion engines and increasing the consumption for on-board air-conditionning systems, while not decre	Rejected. Out of the scope of this section	Government of France	Ministère de la Transition écologique et solidaire	France
71691	74	8	74	8	Ocean and sea energy is widely used in many different ways, not only on what here was put focus. For example ocean/sean energy is used as the "Free cooling" energy energy ssource for cooling of buildings, but nothing here about this.	Noted. The issue of sea water used for air conditioning is now part of section 6.4.2.9. But due to lack of space is not added here.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
7915	74	9	74	14	It is important also to include the ocean current conveyor belt interacts/affected by climate change. Studies has mentioned that because of the Atlantic Ocean's circulation slowed down by about 15% in mid of last century, it has caused hotter summer and colder winter in European countries, precipitation pattern changed in tropics etc. Not only that, the slowed down circulation will also reflecting to the ocean energy like marine current and wave energy may expected to be reduced too.	Rejected. Out of the scope of this section	Cheng Yee Ng	Universiti Teknologi PETRONAS	Malaysia
18255	74	9	74	14	(Section 6.5.1.4) This section on ocean energy is missing any references to levels of confidence / agreement.	Noted. The literature is so brief that this kind of assessment cannot be made.	Government of United Kingdom (of Great Britain and Northern Ireland)	Department for Business, Energy & Industrial Strategy	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
43891	74	9	74	14	Ocean waters are probably one of the most affected area/region in the world from climate change. The catastrophic phenomenon could actually both be beneficial and destructive to the environment. (For the benefit): As the average global ocean surface temperature rises due to increasing volumes of greenhouse gases, there is a seemingly positive impact for ocean thermal energy which relies on the temperature gradient of the ocean water. The larger the temperature difference, the greater the power output that can be generated. However, this temperature increase could damage the marine ecosystem that the ocean protects such as coral reafs (bleaching) and other aquatic animals. Further expand the discussion about the impact of climate change on ocean energy systems by focusing on ocean thermal energy.	Noted. Climate change will indeed affect the ocean. But here we focus on studies of changes that affect energy production, which are very few.	Vince Davidson Pacañot	University of the Philippines Diliman	Philippines
55801	74	9	74	10	"will not" is inappropriate, as statement is not clear over what time period, or what is assumed for ocean energy development.	Accepted. The setence has been clarified. "....global RE extraction and its vulnerability to climate change will not likely impact climate change mitigation."	Government of United States of America	U.S. Department of State	United States of America
21069	74	11	74	11	Sea level impacts only in near-shore zone with larger wave heights due to weaker bathymetric breaking. Ref. Adaptation of coastal structures to mean sea level rise Philippe Sergent1, Guirec Prevot1, Giovanni Mattarolo2, Jérôme Brossard3, Gilles Morel4, Fatou Mar4,5, Michel Benoit2, François Ropert6, Xavier Kergadallan1, Jean-Jacques Trichet1 and Pascal Mallet7 La Houille Blanche Number 6, Décembre 2014 Page(s) 54 - 61 https://doi.org/10.1051/lhb/2014063	Rejected. outside the scope of the section.	Government of France	Ministère de la Transition écologique et solidaire	France
74883	74	15	74	47	In this section we are discussing bioenergy, a definition of bioenergy would be useful. It would also be recommended to use common terminology, bioenergy or biofuels in the entire report	Noted. There is a definition in the WGIII glossary.	Government of Kenya	Kenya Meteorological Service	Kenya
48331	74	18	74	18	This is one instance in which CO2 is discussed, but how about CH4, which is arguably significantly (80 times) more harmful?	Noted. This sentence is talking about the CO2 fertilization effect or the direct effect of increasing carbon dioxide on bioenergy. The indirect effect of CO2 and CH4 through changes in climate are discussed in this section, but the text is agnostic as to which GHG drives changes in climate	Susana Hancock	University of Oxford	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
80637	74	21	74	26	Bioenergy considerations have to recognize that bioenergy is not carbon neutral in the near-term—with a carbon deficit for many years, generally several decades to a century—that is crucial for mitigating emissions and avoiding hitting the 1.5°C mark. Danielle Venton, Core Concept: Can bioenergy with carbon capture and storage make an impact?, PNAS (2016); Leturcq, P. (2020) GHG Displacement Factors of Harvested Wood Products: the Myth of Substitution, Nature Scientific Reports 10:1–9; Mary S. Booth, Not carbon neutral: Assessing the net emissions impact of residues burned for bioenergy, Environ. Res. Lett. 13 (21 February 2018); Sterman J. D., et al. (2018) Does replacing coal with wood lower CO2 emissions? Dynamic lifecycle analysis of wood bioenergy, Envtl. Research Letters 13(015007):1–10, 1 (“We simulate substitution of wood for coal in power generation, estimating the parameters governing NPP and other fluxes using data for forests in the eastern US and using published estimates for supply chain emissions. Because combustion and processing efficiencies for wood are less than coal, the immediate impact of substituting wood for coal is an increase in atmospheric CO2 relative to coal. The payback time for this carbon debt ranges from 44–104 years after clear-cut, depending on forest type—assuming the land remains forest. Surprisingly, replanting hardwood forests with fast-growing pine plantations raises the CO2 impact of wood because the equilibrium carbon density of plantations is lower than natural forests. Further, projected growth in wood harvest for bioenergy would increase atmospheric CO2 for at least a century because new carbon debt continuously exceeds NPP. Assuming biofuels are carbon neutral may worsen irreversible impacts of climate change before benefits accrue. Instead, explicit dynamic models should be used to assess the climate impacts of biofuels.”).	Noted. These issues are discussed in other parts of this report. This section is only about the effects of climate on the production of bioenergy	Durwood Zaelke	Institute for Governance & Sustainable Development	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
80781	74	21	74	26	Bioenergy considerations have to recognize that bioenergy is not carbon neutral in the near-term—with a carbon deficit for many years, generally several decades to a century—that is crucial for mitigating emissions and avoiding hitting the 1.5°C mark. Danielle Venton, Core Concept: Can bioenergy with carbon capture and storage make an impact?, PNAS (2016); Leturcq, P. (2020) GHG Displacement Factors of Harvested Wood Products: the Myth of Substitution, Nature Scientific Reports 10:1–9; Mary S. Booth, Not carbon neutral: Assessing the net emissions impact of residues burned for bioenergy, Environ. Res. Lett. 13 (21 February 2018); Sterman J. D., et al. (2018) Does replacing coal with wood lower CO2 emissions? Dynamic lifecycle analysis of wood bioenergy, Envtl. Research Letters 13(015007):1–10, 1 (“We simulate substitution of wood for coal in power generation, estimating the parameters governing NPP and other fluxes using data for forests in the eastern US and using published estimates for supply chain emissions. Because combustion and processing efficiencies for wood are less than coal, the immediate impact of substituting wood for coal is an increase in atmospheric CO2 relative to coal. The payback time for this carbon debt ranges from 44–104 years after clear-cut, depending on forest type—assuming the land remains forest. Surprisingly, replanting hardwood forests with fast-growing pine plantations raises the CO2 impact of wood because the equilibrium carbon density of plantations is lower than natural forests. Further, projected growth in wood harvest for bioenergy would increase atmospheric CO2 for at least a century because new carbon debt continuously exceeds NPP. Assuming biofuels are carbon neutral may worsen irreversible impacts of climate change before benefits accrue. Instead, explicit dynamic models should be used to assess the climate impacts of biofuels.”).	Noted. These issues are discussed in other parts of this report. This section is only about the effects of climate on the production of bioenergy	Gabrielle Dreyfus	Institute for Governance & Sustainable Development	United States of America
55803	74	43	75	4	What is CO2 fertilization? This concept is mentioned several times in this paragraph, but it is not explained.	Accepted. A definition has been added at the first mention	Government of United States of America	U.S. Department of State	United States of America
24679	75	5	75	39	This section rightly recognises that climate change impacts (increased droughts, water scarcity) would have a potential impact on thermal prower plants. In order to provide a more accurate picture, we would strongly recommend that mention is made to the fact that it is technically feasible to adapt nuclear power plants should droughts/water scarsity become a more significant issue (see for example the Palo Verde NPP located in the Arizona [US] dessert which uses wastewater)	Rejected. Out of the scope of this section	Ann Jessica Johnson	FORATOM (European Atomic Forum)	Belgium
71693	75	5	75	39	Here is the main focus only on the electricity production in Thermal Power Plants, but the TPP's are widely used in countries which needs heating and utilisation of heat from TPP in district heating systems increases TPP efficiency from ~30% (just electricity production) to ~75-85% or even more (electricity+heating). No any risks for cooling water in this case. It looks like the author refer only to countries which do not need any heating and produce electricity in CHP without heat utilisation. From the other point the waste heat from CHP by the help of absorbtion heat pump can be converted to cooling energy and utilised in district cooling systems in high temperature countries.	Taken into account. Literature on climate change impacts on CHP was found limited; however, the potentially less significant impact is mentioned in the revised text.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
28635	75	7	75	8	Water increase with CO2 capture is not necessarily so. The water use of CO2 capture can be managed to not increase, see references: Giannaris, S. et al (2020). “Implementing a second generation CCS facility on a coal fired power station”, Greenhouse Gases: Science and Technology, 10(3), 506-518; Magneschi et al (2017) "The Impact of CO2 Capture on Water Requirements of Power Plants", GHGT-13, Energy Procedia 114 6333-6347 ; IEAGHG (2020) “Understanding the cost of reducing water usage in coal and gas fired power plants with CCS”, IEAGHG 2020-09; IEAGHG (2011) "Evaluation and Analysis of Water Usage of Power Plants with CO2 Capture" IEAGHG 2010/05; IEAGHG (2020) "CCS and the Sustainable Development Goals", IEAGHG 2020-14; Mikunda et al (2020) "CCS and the Sustainable Development Goals", International Journal of Greenhouse Gas Control (submitted 17 Nov 2020); also IPCC (2018) SR1.5 Chap 5 p500 which cites Magneschi.	Taken into account. it is now noted in the text that new designs with minimal impacts on water usage exist; references are also added.	Tim Dixon	IEAGHG	United Kingdom (of Great Britain and Northern Ireland)
5385	75	9	75	9	after Power plants, add : when located along rivers". Those on the coasts are not affected.	Taken into account. The related sentence is modified to highlight rivers.	Michel SIMON	Retraité/ Pdt d'association	France
15549	75	10	75	10	Include solar thermal power, which, in fact, is also a thermal power plant.	Solar thermal power (concentrated solar power, CSP) is discussed in the section 6.5.1.3. For this reasons it is not repeated in the section 6.5.1.6, where other thermal power plants are discussed.	Vladimir Kucinov	National Research Nuclear University "MEPHI" (Moslow Enginiring Physical Institute)	Russian Federation
17423	75	11	75	11	"Increasing ambient and water temperatures will mean reduced generator efficiencies due to reduced thermal efficiencies…" This effect is negligible: thermal efficiency in summer results in ~2% to 3% lower production than in winter in Slovenia with average temperature summer-winter difference 20 K. For climate change difference 2K will thus reduce efficiency for 0.2% - 0.3%.	Taken into account. Numerical results are added to describe the expected level of impact, based on (Cronin et al. 2018)	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
78525	75	11	75	11	"Increasing ambient and water temperatures will mean reduced generator efficiencies due to reduced thermal efficiencies…" This effect is negligible: thermal efficiency in summer results in ~2% to 3% lower production than in winter in Slovenia with average temperature summer-winter difference 20 K. For climate change difference 2K will thus reduce efficiency for 0.2% - 0.3%.	Taken into account. Numerical results are added to describe the expected level of impact, based on (Cronin et al. 2018)	Tomaž Žagar	Faculty for Energy Technology, University of Maribor	Slovenia
51401	75	12	75	20	I think 'thermoelectric' should be replaced by 'thermal power'	Taken into acocunt. Changed as requested.	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
17425	75	17	75	22	Once-through water cooling can be replaced with closed-circuit cooling with moderate investment into cooling towers. There is not need to lose 20% of thermoelectric generation. The same problem will be relevant for solar CSP tehnology - especially in the deserts, where conditions for CSP solar are optimal but the water is scarce.	Noted. The difference of impacts between once through cooling and closed-circuit cooling cooling is noted in the text. The mitigation option of changin cooling technology is mentioned; the section is expanded.	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
78527	75	17	75	22	Once-through water cooling can be replaced with closed-circuit cooling with moderate investment into cooling towers. There is not need to lose 20% of thermoelectric generation. The same problem will be relevant for solar CSP tehnology - especially in the deserts, where conditions for CSP solar are optimal but the water is scarce.	Same comment as comment id 17425: see answer to that comment	Tomaž Žagar	Faculty for Energy Technology, University of Maribor	Slovenia

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
28631	75	28	75	31	Water increase with CO2 capture is not necessarily so. The water use of CO2 capture can be managed to not increase, see references: Giannaris, S. et al (2020). “Implementing a second generation CCS facility on a coal fired power station”, Greenhouse Gases: Science and Technology, 10(3), 506-518; Magneschi et al (2017) "The Impact of CO2 Capture on Water Requirements of Power Plants", GHGT-13, Energy Procedia 114 6333-6347 ; IEAGHG (2020) “Understanding the cost of reducing water usage in coal and gas fired power plants with CCS”, IEAGHG 2020-09; IEAGHG (2011) "Evaluation and Analysis of Water Usage of Power Plants with CO2 Capture" IEAGHG 2010/05; IEAGHG (2020) "CCS and the Sustainable Development Goals", IEAGHG 2020-14; Mikunda et al (2020) "CCS and the Sustainable Development Goals", International Journal of Greenhouse Gas Control (submitted 17 Nov 2020); also IPCC (2018) SR1.5 Chap 5 p500 which cites Magneschi. The papers cited here in SOD Chp6 (Rosa, Byers) whilst recent (2019,2016) have been checked and found to have chosen water use assumptions based only on papers from 2010 and 2011 (Rosa), 2010,2011,2012 (Byers) and so are out of date.	Taken into account. It is now noted in the text that new designs with minimal impacts on water usage exist; references are also added.	Tim Dixon	IEAGHG	United Kingdom (of Great Britain and Northern Ireland)
78641	75	32	75	39	higher shares of VRE (PV, wind) reduce the reliance on thermal power plants and the associated water demand for cooling as clearly concluded by Lohrmann et al. (https://www.nature.com/articles/s41560-019-0501-4) - this should be mentioned as a prime mitigation option. Solar PV and wind energy do not require water for their operation, while some clearning water requirement for solar PV can be recycled in automated cleaning robots, as it is present day standard practice in dry regions	Taken into account. Suggested reference added.	Christian Breyer	LUT University	Finland
45465	75	34	75	39	Dry cooling can be used in thermal plants (including nuclear). Please see: https://doi.org/10.1016/1359-4311(95)00068-2	Taken into acocunt. Dry cooling is added as a possible mitigation option.	Maciej Lipka	National Centre for Nuclear Research	Poland
15109	76	2	76	8	The empirical study on China shows that the effect of temperature change on power consumption for refrigeration is greater than that for heating. Therefore, the temperature rise may lead to a significant increase in electricity consumption. The following literature should be supplemented. Chen Zhang, Hua Liao, Zhifu Mi (2019) Climate impacts: temperature and electricity consumption. Natural Hazards, 99: 1259-1275	Taken into account. The suggested referece has been added.	Guoquan HU	National Climate Center of China Meteorological Adminstration	China
11455	76	5	76	8	Suggest also including the following reference on the influence of extreme heat event on the energy demand : Morakinyo, T.E., C. Ren, Y. Shi, K. K. Lau, H. W. Tong, C. W. Choy and E. Ng, 2019 : Estimates of the impact of extreme heat events on cooling energy demand in Hong Kong, Renewable Energy 142, 73-84	Taken into account. The suggested referece has been added.	SAI MING LEE	Hong Kong Observatory	China
69633	76	16	76	16	Generally higher temperatures would likely increase the fuel consumption in oil-based people transportation, by decreasing the efficiency of internal combustion engines and increasing the consumption for on-board air-conditionning systems, while not decreasing the need for heating habitacles, which are heated from the waste heat of the engines. At the same time, they would likely decrease the energy needs of electric vehicles, ensuring a more efficient behaviour of batteries, while a likely increase of air-conditioning loads is likely to be balanced with a decrease of the heat-pump loads.	Noted. Clarification about transportation consumption is added. Air-condition and heating load balance was considered to be discussed adequately in the existing text.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
71695	76	27	76	29	Increase in load due to climate change should be also set in relation to a stronger electrification of energy applications (esp. in relation to heat pumps and electric mobility).	Taken into account. Impact of electrification has been emphasized.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
69635	76	30	78	12	Heat waves also have an important effect on the running of thermal power plants cooled by rivers, by drying them or simply warming them to levels that are considered dangerous for wildlife; power plants sited along rivers may be put to a halt to avoid that the waste heat (in case of once-through cooling) or the withdrawal of water (in case of evaporative cooling). Such effects have been massive e.g. during the heat wave in France in 2003, when many nuclear power plants have been stopped.	The following is added:"Recent studies investigated the effects of climate change on power systems in the U.S. Pacific Northwest (Turner et al. 2019), Europe (Harang et al. 2020) and China (Chen et al. 2021) suggesting an overall tendency of reducing concerns related to network vulnerability during winters, with pronounced increase of power shortfalls during summers, especially when compound events (increase in peak demand through heat waves and lack of hydropower due to droughts) are considered"	Cédric PHILIBERT	Institut Français des Relations Internationales	France
77389	76	30	78	11	Suggest to include "landslides" to vulnerability. Landslides may cause specific harm to hydropower	Thanks for this. a footnote is added in this regard:"landslides will also impact the hydro power facilities (Water power, 2017)". However due to the space limit we are not able to expand it further.	Atle Harby	SINTEF Energy Research	Norway
11457	76	33	76	37	Suggest also adding the example of multi-hazards (high winds, heavy rain and storm surge/waves) induced by tropical cyclones to coastal power infrastructure.	Accepted. The following is added:"Recent studies investigated the effects of climate change on power systems in the U.S. Pacific Northwest (Turner et al. 2019), Europe (Harang et al. 2020) and China (Chen et al. 2021) suggesting an overall tendency of reducing concerns related to network vulnerability during winters, with pronounced increase of power shortfalls during summers, especially when compound events (increase in peak demand through heat waves and lack of hydropower due to droughts) are considered."	SAI MING LEE	Hong Kong Observatory	China
43893	76	34	76	35	Aside from the catastrophes listed in this section, I encourage you to discuss quite extensively the vulnerability posed by rising sea levels to power generation systems, especially those in low-lying areas. Mimura (2013) [21] emphasized that sealevel rise is a significant effect of climate change with wide-scale threatening impacts especially for coastal regions. Power generation facilities in these areas will be at risk due to intrusion of seawater in the area which could damage critical equipment such as turbines, compressors, and even electrical substations. Hence, new or emerging engineering design of a power generation facility, especially in climate vulnerable areas, should account for the adverse effects of climate change.	Thanks for this. The topic is interesting and important. However, due to space limit we are not able to address this issue here.	Vince Davidson Pacañot	University of the Philippines Diliman	Philippines
48333	76	38	76	41	Brings in the question of quality grids	Accepted. Reference included	Susana Hancock	University of Oxford	United States of America
52247	76	39	76	39	Use of terms resilience, reliability, and adequacy is not consistent through the chapter.	Accepted. Reference included:"Extreme weather and storms manifest as threat vectors to all aspects of the power system in different ways, which affect system resilience, reliability, and adequacy (Moreno et al. 2020). "	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
7885	76	42	76	47	sentence is repeated twice in the paragraph	Accepted. The text has been revised.	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
11459	76	42	76	47	The statement “Climate change will affect both the frequency and intensity of extreme weather events (Seneviratne et al. 2012) and the effect of climate change on power system vulnerability will depend on the degree to which climate alters the frequency and intensity these events.” repeated in this paragraph.	Accepted. The text has been revised.	SAI MING LEE	Hong Kong Observatory	China
17527	76	42	76	47	duplicated sentence	Accepted. The text has been revised.	Alaa Al Khourdajie	IPCC	United Kingdom (of Great Britain and Northern Ireland)
55805	76	42	76	47	There are two consecutive sentences duplicated in this paragraph.	Accepted. The text has been revised.	Government of United States of America	U.S. Department of State	United States of America
10953	76	44	76	47	"Climate change will….and density these events" are overlaped	Accepted. The text has been revised.	Dong-Woon NOH	Korea Energy Economics Institute	Republic of Korea
16377	76	44	76	47	"Climate change will….and density these events" are overlaped	Accepted. The text has been revised.	Government of Republic of Korea	Korea Meteorological Administration (KMA)	Republic of Korea
27729	76	44	76	47	Delete "Climate change will affect both the frequency and intensity of extreme weather events (Seneviratne et al. 2012) and the effect of climate change on power system vulnerability will depend on the degree to which climate alters the frequency and intensity these events.", as this sentence is repeated.	Accepted. The text has been revised.	Eleni Kaditi	Organization of the Petroleum Exporting Countries, OPEC	Austria
71697	76	44	76	47	Sentence is written twice	Accepted. The text has been revised.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
28961	76	47	76	47	I suggest to add after "..these events." evidence from two recent studies: Two recent studies investigated upon the effects of climate change on power systems in the U.S. Pacific Northwest Turner et al. 2019) and Europe (Harang et al. 2020), suggesting a overall tendency decreasing adequacy concerns during winters, with pronunced increase of power shortfalls during summers, especially when compound events (excess peak demand through heat wave and lack of hydropower due to droughts) are considered. (Turner et al. (2019): Compound climate events transform electrical power shortfall risk in the Pacific Northwest; Harang et al. (2020): Incorporating climate change effects into the European power system adequacy assessment using a post-processing method)	Accepted. The following is added:"Recent studies investigated the effects of climate change on power systems in the U.S. Pacific Northwest (Turner et al. 2019), Europe (Harang et al. 2020) and China (Chen et al. 2021) suggesting an overall tendency of reducing concerns related to network vulnerability during winters, with pronounced increase of power shortfalls during summers, especially when compound events (increase in peak demand through heat waves and lack of hydropower due to droughts) are considered."	Fabian Heymann	INESC TEC	Switzerland
6049	76				I am not an expert in this type of analysis, but on the surface I would think that due to the efficiency difference between heating (resistance ~100%) and cooling (compressor) the increased cooling would outweigh the reduced heating significantly.	Rejected. Out of the scope of this section	Adam Burak	University of Michigan	United States of America
10955	77	2	77	5	The explanation is too dificult to understand as a reader	The sentences are updated:"High wind speeds can also lead to disconnections of demand on weaker networks, resulting in customer interruptions. Hurricane conditions can damage wind and solar PV infrastructure. In extreme periods, the system may simultaneously be experiencing high demand at a time when lines are particularly at-risk from mechanical failure from wind and storm related effects. "	Dong-Woon NOH	Korea Energy Economics Institute	Republic of Korea

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
16379	77	2	77	5	The explanation is too dificult to understand as a reader	Accepted. The sentences are updated:"High wind speed can also lead to disconnections of demand on weaker networks, resulting in customer interruptions. Hurricane conditions can damage wind and solar PV infrastructure. In extreme periods, the system may simultaneously be experiencing high demand at a time when lines are particularly at-risk from mechanical failure from wind and storm related effects. "	Government of Republic of Korea	Korea Meteorological Administration (KMA)	Republic of Korea
73989	77	2	77	3	this sentence is confusing	The sentence is updated:"High wind speeds can also lead to disconnections of demand on weaker networks, resulting in customer interruptions"	Heleno Miguel	Lawrence Berkeley National Laboratory	United States of America
42991	77	9	77	16	Wildfires also have secondary impacts of debris flow and deforestation which increase flooding risks.	Thanks for this. The following is added:"Wildfires also have impacts of debris flow and deforestation which increase flooding risks (Neary and Leonard 2019)."	Kurt Kornelsen	Ontario Power Generation	Canada
8891	77	24	77	29	Snow and ice section - possible reference to Texas event.	Thanks for this. The following is added:"Snow and ice buildup can also significantly impact wind turbines as seen recently in Texas (Winter Storm 2021)"	Seth Dunn	ServiceMax	United States of America
42993	77	24	77	29	Snow and ice build up can also significantly impact wind turbines as seen recently in Texas.	Thanks for this. The following is added:"Snow and ice buildup can also significantly impact wind turbines as seen recently in Texas (Winter Storm 2021)"	Kurt Kornelsen	Ontario Power Generation	Canada
43601	77	24	77	29	Wet snow accumulation on cables can be particularly problematic, particularly in southern EU. See: Llasat M.C., Turco M., Quintana-Seguí P. and Llasat-Botija M. (2014). The snow storm of 8 March 2010 in Catalonia (Spain): a paradigmatic wet-snow event with a high societal impact. Natural Hazards and Earth System Sciences, 14(2), 427. Bonelli P., Lacavalla M., Marcacci P., Mariani G. and Stella G. (2011) Wet snow hazard for power lines: a forecast and alert system applied in Italy, Nat. Hazards Earth Syst. Sci., 11, 2419-2431 Croce P., Paolo Formichi, Filippo Landi, Paola Mercogliano, Edoardo Bucchignani, Alessandro Dosio, Silvia Dimova, The snow load in Europe and the climate change, Climate Risk Management, 20, pp. 138-154, 2018.	The following sentence is updated:"Snow can also lead to flashovers on lines due to wet snow accumulation (e.g., particularly problematic in southern EU (Croce et al. 2018)) on insulators (Yaji et al. 2014)." Due to space limit we were unable to expand further.	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy
42995	77	30	78	5	Hydropower plants and dam are especially exposed to flooding. Prudent Dam Safety criteria can build reslience but aging infrastructure and underinvestment continue to be problems. The American Society of Civil Engineers continually gives poor ratings to the state of US dam infrastructure.	Thanks for this. The following reference is also added to the text related to hydropower:"(Azevedo de Almeida, B. and Mostafavi, A., 2016). "	Kurt Kornelsen	Ontario Power Generation	Canada
73991	77	30	77	30	low-lying substations and underground distribution cables	Added	Heleno Miguel	Lawrence Berkeley National Laboratory	United States of America
73993	77	31	77	32	"route power around the power system" is an unclear expression.	Thanks for this - description modified:"Flooding presents as a threat to the transmission and distribution systems by inundating low-lying substations and underground cables, which affects both the ability to deliver power to customers connected behind the substation and the ability to reroute power flows by changing network topology, if feasible. "	Heleno Miguel	Lawrence Berkeley National Laboratory	United States of America
10657	77	40	78	3	There is a major redundancy between p77 L40-45 and the last 6 lines of the paragraph.	Thanks for this. Fixed	Philippe Waldteufel	CNRS	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
17427	77	40	77	42	"Fukushima …severe ... health impacts". Fukushima accident did not cause severe healt impacts (reference https://www-pub.iaea.org/MTCD/Publications/PDF/AdditionalVolumes/P1710/Pub1710-TV1-Web.pdf)	Thanks for this. "Health impact" is removed	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
55807	77	40	78	3	There are three consecutive sentences duplicated in this paragraph.	Accepted. The duplicate sentence has been deleted.	Government of United States of America	U.S. Department of State	United States of America
61827	77	40	77	42	"As Fukushima (Steinhauser et al. 2014) illustrates, coastal flooding of power stations can have severe and long-lasting effects causing not only massive loss of generating capacity but severe socioeconomic and health impacts, as well." First, (Steinhauser et al. 2014) discusses nuclear accidents, not flooding. Secondly, the analysis by IAEA states: "No observations of direct radiation induced effects in plants and animals have been reported, although limited observational studies were conducted in the period immediately after the accident. There are limitations in the available methodologies for assessing radiological consequences, but, based on previous experience and the levels of radionuclides present in the environment, it is unlikely that there would be any major radiological consequences for biota populations or ecosystems as a consequence of the accident" (IAEA, 2015, ISBN: 978-92-0-107015-9, https://www.iaea.org/publications/10962/the-fukushima-daiichi-accident).	Thanks for this. "Health impact" is removed	Rauli Partanen	Think Atom	Finland
65861	77	40	77	42	"As Fukushima (Steinhauser et al. 2014) illustrates, coastal flooding of power stations can have severe and long-lasting effects causing not only massive loss of generating capacity but severe socioeconomic and health impacts, as well." Firstly, Steinhauser et al. discusses only nuclear accidents. Secondly, the analysis by IAEA states that "No observations of direct radiation induced effects in plants and animals have been reported, although limited observational studies were conducted in the period immediately after the accident. There are limitations in the available methodologies for assessing radiological consequences, but, based on previous experience and the levels of radionuclides present in the environment, it is unlikely that there would be any major radiological consequences for biota populations or ecosystems as a consequence of the accident" (IAEA, 2015, ISBN: 978-92-0-107015-9, https://www.iaea.org/publications/10962/the-fukushima-daiichi-accident). Revise accordingly.	Thanks for this. "Health impact" is removed	Eero Hirvijoki	Aalto University	Finland
78529	77	40	77	42	"Fukushima …severe ... health impacts". Fukushima accident did not cause severe healt impacts due to radiatoin. (reference https://www-pub.iaea.org/MTCD/Publications/PDF/AdditionalVolumes/P1710/Pub1710-TV1-Web.pdf)	Thanks for this. "Health impact" is removed	Tomaž Žagar	Faculty for Energy Technology, University of Maribor	Slovenia
77243	77	42			The "health impacts" stated for Fukushima do not reflect the conclusions of the UNSCEAR report, and should be removed.	Thanks for this. "Health impact" is removed	Giacomo Grasso	ENEA	Italy
65863	77	44	78	3	Includes accidential repetition of the text. Remove the extra.	Accepted. The duplicate sentence has been deleted.	Eero Hirvijoki	Aalto University	Finland
8791	77	46	78	3	Delete these lines as they duplicate text above.	Accepted. The duplicate sentence has been deleted.	Chris Vivian	Retired ex Cefas	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
27731	77	46	78	3	Delete "As Fukushima (Steinhauser et al. 2014) illustrates, coastal flooding of power stations can have severe and long-lasting effects causing not only massive loss of generating capacity but severe socioeconomic and health impacts, as well. Hurricane Katrina illustrated the potentially calamitous effects of flood defense failure and such risk and its impact on the power system is difficult to quantify (Ji and Wei 2015). Given the tendency of major developed cities to be in coastal or river-adjacent areas this is a severe threat that needs to be more fully understood.", as these sentences are a repetition.	The repetition is removed.	Eleni Kaditi	Organization of the Petroleum Exporting Countries, OPEC	Austria
43603	77	46	78	3	Repeated sentences from lines 40-45 page 77	Accepted. The duplicate sentence has been deleted.	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy
77245	77	46	78	3	The entire block is an exact duplication of that at page 77, lines 40-45. Remove.	Accepted. The duplicate sentence has been deleted.	Giacomo Grasso	ENEA	Italy
71699	77	48	78	3	Sentence is written twice	Accepted. The duplicate sentence has been deleted.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
15551	78	13	78	42	Nuclear power should be included in the box 6.4 because it has little impact on local climatic conditions. (Nuclear Power and Sustainable Development, IAEA, Vienna 2016.)	Rejected. Out of the scope of the box, which focus only on the technologies that potentially have climate impacts.	Vladimir Kucinov	National Research Nuclear University "MEPHI" (Moslow Enginiring Physical Institute)	Russian Federation
64329	78	13	78	42	If the above comments are taken on board, then Box 6.4 would need to include improved air quality where local waste and environmental energy sources are used for building heating.	Rejected. Out of the scope of the box, which focus only on the technologies that potentially have climate impacts.	Peter North	Imperial College (part-time PhD student) /Calorem Ltd	United Kingdom (of Great Britain and Northern Ireland)
55809	78	17	78	29	While not an exact contradiction, this paragraph contains a sentence that says that solar PV in urban settings can produce a cooling effect, but also contains a sentence that says the conversion of solar-generated electricity to heat causes increases in global temperatures, particularly in urban areas. How do these two sentences interact?	Taken into account. The first statements are based on measurements, while the later ones on modeling. Also, "global" -> "local" in Line 17.	Government of United States of America	U.S. Department of State	United States of America
2691	78	26	78	28	“increases regional and global temperatures”. I think you mean “local”.	Accepted. The sentence has been changed.	Jan Wohland	ETH Zurich	Switzerland
48139	78	30	78	38	The paper below found that wind turbines installed worldwide to power ~38% of the world's all-purpose energy in 2050 (~13 TW nameplate) would reduce global warming by about 3% due to the net cooling of wind turbines on the atmosphere. Whereas, turbines cause a slight warming of the ground downwind of them due to lower evaporation, that is offset by cooling of the air due to less condensation in the air. However, because wind turbines cause a net reduction in water vapor, a greenhouse gas, they cause a net global cooling. None of the other papers cited looked at this from a global perspective. The following paper contains the analysis: Jacobson, M.Z., M.A. Delucchi, M.A. Cameron, and B.V, Mathiesen, Matching demand with supply at low cost among 139 countries within 20 world regions with 100% intermittent wind, water, and sunlight (WWS) for all purposes, Renewable Energy, 123, 236-248, 2018. This paper (page 15,683) discusses the original theory as to why turbines cool the climate: Jacobson, M.Z., and C.L. Archer, Saturation wind power potential and its implications for wind energy, Proc. Nat. Acad. Sci., 109, 15,679-15,684, doi:10.1073/pnas.1208993109, 2012,	Partially taken into account. We have added a sentence that modifications to the surface could have other consequences to the climate system.	Mark Jacobson	Stanford University	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
2693	78	33	78	34	Why not mention Vautard et al.s results?`I think that they found only small impacts.	Accepted. The sentense has been modified for clarification	Jan Wohland	ETH Zurich	Switzerland
42997	78	42	78	42	emissions generally decrease overtime in most reservoirs.	Accepted. The sentence has been changed to "...these impacts vary greatly among facilities and decrease over time."	Kurt Kornelsen	Ontario Power Generation	Canada
81891	79	1	98	21	In this section, it would be important to comment on the role of legal and tax issues, not only of energy and technical management ones, when dealing with the possible development of CCUS technologies. For example, without stringent regulations limiting CO2 emissions or a high carbon tax, management alone would probably not be enough to reach a deployment of CCUS facilities large enough to give a sizeable contribution to the achieveent of the goals outlined in the Paris Agreement.	While these topics are interesting and important, space limits prevent us from addressing them here.	Pietro Guarato	Université de Lausanne	Switzerland
85451	79	1	79	1	I would start every section with a paragraph telling the reader what is going to be in the paragraph. So I think it is important to add one here as well.	Noted. We have attempted to provide roadmaps/introductions in each section, though space constraints prevent us from including additional text.	Auke Hoekstra	Eindhoven University of Technology	Netherlands
43895	79	2	79	2	It will be helpful if this part of the report clarifies what really "net zero emissions" mean. In contrary to what other sources may have defined, the term "net zero" does not necessarily mean "absolute zero". Net zero emissions (or carbon-neutral emissions) mean that the amount of greenhouse gas emissions released in the atmosphere is equal to (or more favorably less than) the amount of GHG emissions absorbed from the atmosphere. Continuous consumption of fossil fuel energy resources does not promote nor even achieve the net zero scenarios modelled by climate scientists. Attempting to achieve net zero emissions would need the reduction of fossil fuel consumption coupled with a consequent increase in renewable energy utilization and energy effiiency and conservation measures (which has a potential to reduce 40% of the global GHG emissions). This is an ideal setting especially for countries who still rely on fossil fuels, majority of which are developing countries with an exponentially growing population.	The third paragraph of this section discusses the definitions of "net zero" systems and some of the complexities involved, including distinguishing between net zero and "absolute zero" (i.e., introducing the idea that emissions do not need to be zero everwhere for all sources to reach net-zero levels).	Vince Davidson Pacañot	University of the Philippines Diliman	Philippines
43001	79	3	79	8	Net zero should be more clearly defined. The definition given is "CO2 emissions from the energy sector be reduced to near zer or even below zero". However, there remains a degree of ambiguity within industry without a firm definition of what counts as net zero. For example, if a power plant had an increase in efficiency most companies would consider this a carbon offset...There is no accepted term to which this offset would apply. Some companies are undertaking projects to build transmission capacity, allowing hydropower to be sent to a jurisdiction dominated by fossil fuel. This reduces overall emissions, but who claims credit for the reduction and for how long does this apply? Carbon accounting continues to be problematic because of a lack of agreed to practices and market rules. This leads to double counting and ambiguity.	The third paragraph in the section provides definitions for "net zero" systems and introduces some of the complexities associated with it, including providing a reference that goes into much greater detail on the topic. Unfortunately, space constraints will not allow us to unpack some of these complexities further in the introduction, but the subsequent sections do provide greater detail.	Kurt Kornelsen	Ontario Power Generation	Canada
52279	79	3	79	4	Limiting warming to 1.5 °C or well below 2 °C, ultimately requires that CO2 emissions from the energy sector be reduced to near zero or even below zero" a reference for this strong statement is missing. p.44 states that CCUS combined with FF can provide a path to near-zero	We added a reference to an earlier chapter of the report with additional information.	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
10957	79	4	79	4	delete ")" in "…zero or even below zero.)."	This typo was corrected.	Dong-Woon NOH	Korea Energy Economics Institute	Republic of Korea

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
16381	79	4	79	4	delete ")" in "…zero or even below zero.)."	This typo was corrected.	Government of Republic of Korea	Korea Meteorological Administration (KMA)	Republic of Korea
17529	79	4	79	4	".)." missing confidence statement?	This typo was corrected.	Alaa Al Khourdajie	IPCC	United Kingdom (of Great Britain and Northern Ireland)
43605	79	4	79	4	Remove ")."	This typo was corrected.	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy
62011	79	6	79	6	Typo: change "sector be reduced to near zero or even below zero.)." to "sector be reduced to near zero or even below zero."	This typo was corrected.	Esa Vakkilainen	LUT University, Lappeenranta	Finland
7887	79	15	79	15	in terms of the point in time at which net anthropogenic CO2 emissions reach zero, accompanied by substantial reductions in non-CO2 emissions (IPCC 2018). This would be a good point to mention that it the important metric is not the point in time when net-zero is reached - but the cumulative GHG emissions that have taken place until this point.	We added "cumulative net emissions over time" to this sentence.	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
71701	79	17	79	19	Please add source(s) for this statement.	We moved the Levin, et al. (2020) reference from the previous sentence to this one.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
71703	79	20	79	30	While it makes sense to shortly discuss the role of net-zero energy systems in a climate-neutral economies, I don't think this complicates the characterisation of a net-zero energy system, Please avoid this impression.	In this paragraph and subsequent subsections, we describe how the "net zero" is defined can impact the description of the net-zero system.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
12023	79	25	79	28	Requires reference - suggest Chatterjee, S., Huang, KW. Unrealistic energy and materials requirement for direct air capture in deep mitigation pathways. Nat Commun 11, 3287 (2020). https://doi.org/10.1038/s41467-020-17203-7	We added a reference to this statement.	Paul Rouse	Carnegie Climate Governance Initiative (C2G) - The Carnegie Council for Ethics and International Affairs	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
80639	79	30	79	33	BECCS is not carbon neutral in the near-term—with a carbon deficit for many years, generally several decades to a century—that is crucial for mitigating emissions and avoiding hitting the 1.5°C mark. Further, when coupled with CCS, leakage in the supply chain make it highly inefficient (European Academies, 2020). CITATIONS: Danielle Venton, Core Concept: Can bioenergy with carbon capture and storage make an impact?, PNAS (2016); Leturcq, P. (2020) GHG Displacement Factors of Harvested Wood Products: the Myth of Substitution, NATURE SCIENTIFIC REPORTS 10:1–9; Mary S. Booth, Not carbon neutral: Assessing the net emissions impact of residues burned for bioenergy, ENVIRON. RES. LETT. 13 (21 February 2018); Sterman J. D., et al. (2018) Does replacing coal with wood lower CO2 emissions? Dynamic lifecycle analysis of wood bioenergy, ENVTL. RESEARCH LETTERS 13(015007):1–10, 1 (“We simulate substitution of wood for coal in power generation, estimating the parameters governing NPP and other fluxes using data for forests in the eastern US and using published estimates for supply chain emissions. Because combustion and processing efficiencies for wood are less than coal, the immediate impact of substituting wood for coal is an increase in atmospheric CO2 relative to coal. The payback time for this carbon debt ranges from 44–104 years after clear-cut, depending on forest type—assuming the land remains forest. Surprisingly, replanting hardwood forests with fast-growing pine plantations raises the CO2 impact of wood because the equilibrium carbon density of plantations is lower than natural forests. Further, projected growth in wood harvest for bioenergy would increase atmospheric CO2 for at least a century because new carbon debt continuously exceeds NPP. Assuming biofuels are carbon neutral may worsen irreversible impacts of climate change before benefits accrue. Instead, explicit dynamic models should be used to assess the climate impacts of biofuels.”). European Academies’ Science Advisory Council (2020) Commentary on Forest bioenergy, carbon capture and storage, and carbon dioxide removal: an update, 6 (“A key question raised in our earlier analysis [5] was the degree to which the [carbon	While these topics are interesting and important, space limits prevent us from addressing them here, though other sections of the chapter and report go into greater depth on these issues.	Durwood Zaelke	Institute for Governance & Sustainable Development	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
80783	79	30	79	33	BECCS is not carbon neutral in the near-term—with a carbon deficit for many years, generally several decades to a century—that is crucial for mitigating emissions and avoiding hitting the 1.5°C mark. Further, when coupled with CCS, leakage in the supply chain make it highly inefficient (European Academies, 2020). CITATIONS: Danielle Venton, Core Concept: Can bioenergy with carbon capture and storage make an impact?, PNAS (2016); Leturcq, P. (2020) GHG Displacement Factors of Harvested Wood Products: the Myth of Substitution, NATURE SCIENTIFIC REPORTS 10:1–9; Mary S. Booth, Not carbon neutral: Assessing the net emissions impact of residues burned for bioenergy, ENVIRON. RES. LETT. 13 (21 February 2018); Sterman J. D., et al. (2018) Does replacing coal with wood lower CO2 emissions? Dynamic lifecycle analysis of wood bioenergy, ENVTL. RESEARCH LETTERS 13(015007):1–10, 1 (“We simulate substitution of wood for coal in power generation, estimating the parameters governing NPP and other fluxes using data for forests in the eastern US and using published estimates for supply chain emissions. Because combustion and processing efficiencies for wood are less than coal, the immediate impact of substituting wood for coal is an increase in atmospheric CO2 relative to coal. The payback time for this carbon debt ranges from 44–104 years after clear-cut, depending on forest type—assuming the land remains forest. Surprisingly, replanting hardwood forests with fast-growing pine plantations raises the CO2 impact of wood because the equilibrium carbon density of plantations is lower than natural forests. Further, projected growth in wood harvest for bioenergy would increase atmospheric CO2 for at least a century because new carbon debt continuously exceeds NPP. Assuming biofuels are carbon neutral may worsen irreversible impacts of climate change before benefits accrue. Instead, explicit dynamic models should be used to assess the climate impacts of biofuels.”). European Academies’ Science Advisory Council (2020) Commentary on Forest bioenergy, carbon capture and storage, and carbon dioxide removal: an update, 6 (“A key question raised in our earlier analysis [5] was the degree to which the [carbon	While these topics are interesting and important, space limits prevent us from addressing them here, though other sections of the chapter and report go into greater depth on these issues.	Gabrielle Dreyfus	Institute for Governance & Sustainable Development	United States of America
66709	79	36	79	37	You state: 'Note that the focus here is on energy systems with net-zero CO2 emissions from fossil fuels and industrial processes'. I thik it would be more correct to state 'Note that the focus here is on energy systems with net-zero CO2 emissions from energy combustion and industrial processes'.	We revised this sentence to include "combustion" rather than just "fossil fuels".	Chiodi Alessandro	E4SMA	Italy
52249	79	38	79	38	"emissions of non-CO2 emissions" is redundant.	We removed "emissions of" from this sentence.	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
28423	80	1	86	29	Note that with these scenarios are based on cost assumptions noten in Figure 15.7 (Chapter 15), looking at cost declines in renewables their share could be further increased	Noted. We discuss cost assumptions in the literature and their potential impacts on energy system outcomes vis-à-vis other factors in later subsections.	Naud Loomans	Eindhoven University of Technology	Netherlands
50073	80	1	80	7	AR6 scenario database should be used, instead of SR15.	The updated version of the chapter uses the AR6 scenario database.	Masahiro Sugiyama	University of Tokyo	Japan
66707	80	1	80	1	In my opinion figure 6.21 shall be improved. It is not straight forward to understand to which bars legends correspond. Maybe some arrows could help	We moved the labels to make these associations clearer.	Chiodi Alessandro	E4SMA	Italy

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
86601	80	1	80	7	This figure is based on the Special Report database which I believe is mostly quite old and hence innapropriate for this report. Although the report was produced in 2018 the majority of the modelled scenarios are still the same as was included in AR5. At very least this should use the AR6 database. However, I am not seeing much in the way of updates to cost and deployment data in the AR6 results so I suspect this will not give a good coverage of current trends. By this I mean the rate at which renewables are declining in costs (see Way, Mealy, Farmer 2020) it is very unlikely that the range of residual emissions from the energy presented here is not representative of scenarios in which much more of the fossil fuel system is replaced, as current trends appear to suggest, but IAMs model runs do not reflect.	The updated version of the chapter uses the AR6 scenario database. We discuss cost assumptions in the literature and their potential impacts on energy system outcomes vis-à-vis other factors in later subsections.	Matthew Ives	University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
10659	80	9	80	16	There is nothing wrong with this paragraph, except that its information content is especially weak. This is just a list of banalities.	Noted.	Philippe Waldteufel	CNRS	France
28895	80	9	80	16	Please see Chapter 18 WGII	We added a reference to Chapter 18 WGII.	Nathalie Hilmi	Centre Scientifique de Monaco	France
82285	80	9	80	16	In the text you refer to "Section 6.6.5", but this section is missing (so I have difficult to review this section).	The reference was changed to Section 6.6.4.	Anna Krook-Riekkola	Luleå University of Technology	Sweden
85457	80	9	80	10	Configurations of net-zero energy systems will vary by region but are likely to share several common characteristics (high confidence). This meaningless phrase kicks off the 14 pages of section 6.6.2. I would advise dropping this sentence and writing an introductory paragraph that details: 1) What readers are going to find in the next 14 pages, 2) Why it matters, and 3) What the main conclusion is. (And hopefully the conclusion is more breathtaking than the observation that the systems will be different in different regions but also share some characteristics.)	Noted. Unfortunately, space constraints limit expanding this section further.	Auke Hoekstra	Eindhoven University of Technology	Netherlands
62013	80	13	80	13	Typo: change "energy systems (Van Vuuren et al. 2018 Krey et al. 2019 ; Bistline et al. 2019 ; Smith et al. 2016)." to "energy systems (Van Vuuren et al. 2018; Krey et al. 2019 ; Bistline et al. 2019 ; Smith et al. 2016)."	This typo was corrected.	Esa Vakkilainen	LUT University, Lappeenranta	Finland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
82287	80	17	80	31	I don't fully agree with your first sentence. There exist several detailed net-zero energy system pathways in the system modeling literature. They may not also include a detailed analysis about which policies to include and infrastructure needs, but they do exists. Many TIMES models include all sectors (both supply sectors and demand sectors), have a detailed description of each sector and also include process based emissions (hence capture all CO2 emissions). I propose to start the section (row 17) with stating what exists, e.g. using the following reference • Giannakidis G., Karlsson K., Labriet M., Gallachóir B. (eds) (2018) Limiting Global Warming to Well Below 2 °C: Energy System Modelling and Policy Development. Lecture Notes in Energy, vol 64. Springer, Cham. https://doi.org/10.1007/978-3-319-74424-7 It includes several studies modeling pathways on how to get to net-zero CO2 emissions (identifying when to do what in which sector). There is no model that can capture everything. In the following study, we did an attempt to combine qualitative and quantitative approach so target this (the model results are provided to the AR6 database). • Millot A., Krook-Riekkola A., Maïzi N. (2020) Guiding the future energy transition to net-zero emissions: Lessons from exploring the differences between France and Sweden. Energy Policy, Volume 139. https://doi.org/10.1016/j.enpol.2020.111358	We rewrote this sentence to reflect the emerging evidence base and cited a recent review article, which cites many of the studies mentioned: "Types of net-zero energy systems have been emerging in the detailed systems modeling literature in recent years (Azevedo, et al., 2021)."	Anna Krook-Riekkola	Luleå University of Technology	Sweden
85453	80	20	80	21	"though more detailed studies are emerging".	We rewrote this sentence to reflect the emerging evidence base and cited a recent review article: "Types of net-zero energy systems have been emerging in the detailed systems modeling literature in recent years (Azevedo, et al., 2021)."	Auke Hoekstra	Eindhoven University of Technology	Netherlands
85459	80	20	80	21	"though more detailed studies are emerging" By our count there are now 400 studies that are temporally detailed (although often not spatially detailed and not providing pathways). I think it would be strange not to mention trailblazers like Mark Z Jacobson, Christian Breyer and Tom Brown here. E.g. https://doi.org/10.1016/j.egypro.2014.01.154 https://doi.org/10.1016/j.apenergy.2020.116273 https://doi.org/10.1016/j.energy.2008.04.003 https://doi.org/10.1016/j.apenergy.2010.03.001 https://doi.org/10.1016/j.apenergy.2010.03.006. https://doi.org/10.1007/s11027-019-9847-y	We rewrote this sentence to reflect the emerging evidence base and cited a recent review article: "Types of net-zero energy systems have been emerging in the detailed systems modeling literature in recent years (Azevedo, et al., 2021)."	Auke Hoekstra	Eindhoven University of Technology	Netherlands
10959	80	21	80	21	insert ")" at the end of "(e.r., Capros et al. 2019. " ?	This typo was corrected.	Dong-Woon NOH	Korea Energy Economics Institute	Republic of Korea
16383	80	21	80	21	insert ")" at the end of "(e.r., Capros et al. 2019. " ?	This typo was corrected.	Government of Republic of Korea	Korea Meteorological Administration (KMA)	Republic of Korea
62015	80	21	80	21	Typo: change "studies are emerging (e.g., Capros et al. 2019." to "studies are emerging (e.g., Capros et al. 2019)."	This typo was corrected.	Esa Vakkilainen	LUT University, Lappeenranta	Finland
66711	80	21	80	21	Parentesis not closed: (Capros et al 2019	This typo was corrected.	Chiodi Alessandro	E4SMA	Italy

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
82289	80	21	80	21	A bracket is missin: (e.g. Capros et al. 2019)	This typo was corrected.	Anna Krook-Riekkola	Luleå University of Technology	Sweden
85455	80	29	80	30	On the challenges of IAMs I think it's important to add they often trail in assumptions that are used for important parameters like the price of solar, wind, batteries, hydrogen, electric vehicles (things I consider the most important variables in a future low carbon energy system). You could link to chapter 15 figure 15.7 to illustrate this point and to stay consistent in the AR6. I think it's really important not to 'forget' to mention this, even though some in the IAM community might consider it unwelcome disclosure. I could imagine adding a sentence to line 32 like: "Furthermore, the energy community tends to use more recent numbers on energy than the IAM community, for example regarding the price of wind and solar (see chapter 15, figure 15.7)."	While these topics are interesting and important, space limits prevent us from addressing them here, though they are discussed in greater depth later in the chapter.	Auke Hoekstra	Eindhoven University of Technology	Netherlands
85479	80	44	80	44	With all due respect to Jenkins et al. 2018b (who's study is referenced ten times in the chapter!) his model concluded that 100% renewables required either prohibitive amounts of batteries or nuclear. But this conclusion was a direct result from leaving out both biomass and seasonal storage, which is a big no-no when modelling fully renewable systems. (I also corresponded with Jesse Jenkins about this and this thread of another experienced 100% RE modellers makes the problem clear step by step: https://twitter.com/nworbmot/status/1024646209443717120). So the main thing I learned from Jenkins 2018b is that you need either seasonal storage or biomass or some "firm" resource like nuclear (as the chapter mostly states by the way). I think it would help to direct readers to more complete models of actual trailblazers like Mark Z Jacobson (I know, he started a lawsuit), Christian Breyer and Tom Brown. (Full disclosure: I have not worked together with them but get a lot of inspiration from their work.) For Breyer, my first picks would be: 1) for a review https://doi.org/10.1016/j.energy.2019.03.092 2) 2) for the latest model including sector coupling with heating https://doi.org/10.1016/j.apenergy.2020.116273	Thank you for these suggestions. While these are good references, they do not seem to fit in the passage mentioned, which also doesn't discuss Jenkins, et al. (2018b). Note that this particular paper receives more mentions in other sections in the chapter in part due to the fact that it is a review paper. In other instances, we have used reviews and multi-model studies (as opposed to individual studies) to give a broader sense of what the literature says in terms of robust insights and areas of disagreement.	Auke Hoekstra	Eindhoven University of Technology	Netherlands
15553	80				In the figure 6-22 b there is no nuclear power as an energy resource that does not emit CO2 into the atmosphere. It should be corrected. https://www.iea.org/reports/world-energy-outlook-2020	Noted. Nuclear power is implicitly included in the horizontal axis, which plots the share of primary energy from renewables, suggesting that nuclear and other technologies make up the remaining shares. Unfortunately, space does not allow us to include separate panels for all technologies, though we do include references later that discuss nuclear and other technologies in greater detail.	Vladimir Kucinov	National Research Nuclear University "MEPHI" (Moslow Enginiring Physical Institute)	Russian Federation
10661	81	1	81	2	Unlike what this sentence seems to promise, figure 6.22 gives no information about common characteristics of net-zero energy systems.	The headings on each panel of this figure align with the characteristics in Box 6.5 and subsequent sections.	Philippe Waldteufel	CNRS	France
17429	81	1	81	1	Figure 6.22 - curves at the sides not explained	We include an explanation that "probability density distributions shown along each axis" for each panel.	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
37213	81		81		Fig 6.22 a: Axes of the figure are not clear	We enhanced the figure resolution so that the labels are clearer.	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
37729	82	8	82	9	Why not add an additional bullet to Box 6.5 and describe high penetration of nuclear under that bullet. There are enough references in the literature in support of such a description. For example, Berger et al, 2017 as given in chapter 3, and Berger et al., 2017 'Nuclear energy and bio energy carbon capture and storage, keys for obtaining 1.5°C mean surface temperature limit', Int. J. Global Energy Issues, Vol. 40, Nos. 3/4, pp.240–254.	"High penetration of nuclear" does not seem like a robust and generalizable finding in the literature, so it is not included here.	Ravi B Grover	Homi Bhabha National Institute	India
64331	82	8	82	10	Regarding the use of waste heat, the characteristic of such an energy system is 'More effective use of energy by reusing'.	Greater detail on these points is provided in Section 6.6.2.5, and space constraints prevent greater text from being added to this introduction.	Peter North	Imperial College (part-time PhD student) /Calorem Ltd	United Kingdom (of Great Britain and Northern Ireland)
78249	82	8	82	9	Omission - Literature is available supporting high penetration of nuclear, a point may be added for the same. Examples: Int. J. Global Energy Issues, Vol. 40, Nos. 3/4, pp.240–254, Berger et al, 2017 as given in chapter 3, and Berger et al., 2017 'Nuclear energy and bio energy carbon capture and storage, keys for obtaining 1.5°C mean surface temperature limit'.	"High penetration of nuclear" does not seem like a robust and generalizable finding in the literature, so it is not included here.	Reetesh Chaurasia	Department of Atomic Energy, Government of India	India
84489	82	8	82	9	Box 6.5 may be supported with additional references and/or figures supporting the common characteristics.	Figure 6.22 and subsections of 6.6.2 go into greater depth on these common characteristics.	Siir KILKIS	The Scientific and Technological Research Council of Turkey	Turkey
47053	82	9	82	9	Are there any examples of energy systems that are linked to nearby natural carbon sinks? Because that should also count as a means of carbon dioxide removal, if not more cost-effective in some cases.	Carbon removal is discussed in greater detail in Section 6.6.2.7.	John Leo Algo	Living Laudato Si' Philippines	Philippines
43897	82	14	82	16	The persistence of fossil fuels as a primary energy source in the coming years (on or beyond 2030) depends on how dependent the countries from these carbon-intensive resources. Some power plants (especially coal and natural gas) have life spans that extends beyond 2030, a critical rear to achieve short-term climate change mitigation targets. To decide whether to shut down these power plants is an important yet critical decision to make. Shutting down fossil-fired power plants well within their respective life spans would make them stranded assets. These stranded assets entail stranded costs which will definitely be shouldered by consumers. Thus, such move has a high possibility of increasing the electricity price in a region, thereby burdening the people. Strategic deployment of variable renewable energy systems is critical in the future of fossil fuel consumption.	Thank you for the comment. The revised text mentions existing infrastructure, with reference to Tong et al. 2019.	Vince Davidson Pacañot	University of the Philippines Diliman	Philippines
43607	82	15	82	16	Add something along the lines of "and no specific policy or regulation restrict their use" after "non-fossil energy".	Thank you for the comment. Climate and energy policies are mentioned in the prior sentence, such that costs in the sentence are understood to include such policies.	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
69637	82	19	82	20	Besides energy density and specific energy (a.k.a. "gravimetric" density), a more decisive criterion might be the existence of absence of alternatives. Exploring all final uses of fossil fuels, it occurs that only one application actually requires the high density and specific energy of hydrocarbons - and that's aviation (see e.g. Liebreich, M. 2019, Separating Hype from Hydrogen, Part One and Part Two; Philibert, C. 2020, Perspectives on a hydrogen strategy for the European Union, Insitut Français des Relations Internationales). These hydrocarbon, mostly kerosene (more specifically Jet-Fuel A), could be substituted with synthetic kerosene with recycled carbon (captured from the air or from biomass) and renewables-based hydrogen. However, it has been shown that the energy and capital costs of synthesing kerosene would be more expensive than the sequestration of CO2 captured from the air (thus CDR) and the use of fossil-based kerosene (see, e.g., Deben, 2019, Net-zero and the approach to international aviaition and shipping emissions, letter from the Chairman of the UK Committee on Climate Change to Rt Hon Grant Shapps, 24 September). DAC or BEC would be necessary in either case, but sequestration + fossil-based kerosene (in a world with no much reduced use of oil, hence low oil prices) would (according to Lord Deben and the UK CCC) cost less than producing green H2 plus Fischer-Tropsch. Hence kerosene could possibly be used continuously by aviation and fully compensated by CDR, i.e. BECCS or DACCS. On the other hand, synthetic paraffinic kerosene contains lesser impurities than oil-based kerosene and its use could reduce the non-CO2 climate impacts of long-haul (long-distance) aviation. In any case, aviation might be the most compelling justification of conitnuous use of a fossil fuel in a net zero emissions world.	Thank you for the comment. Indeed, such alternative fuels and the related economics are discussed in section 6.6.2.4.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
69639	82	22			I wonder if "flexibility" is the proper word here. Is this real flexibility or simply uncertainty?	Thank you. We opted for the word "flexibility" to indicate that there the magnitude of such fuel use could conceivably vary in functioning net-zero emissions energy systems.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
66713	82	23	82	32	Figure caption doesn't seem correct. No indication of liquid/gaseous fuels in Figure 6.22	Thank you. The electrification and efficiency panels in the figure show the share of energy use not electrified--which still use fuels--and the magnitude of residual emissions in scenarios. The revised text points to those panels.	Chiodi Alessandro	E4SMA	Italy
71705	82	23	82	25	Unclear sentence. In my understanding, the main factor is the cost-competitiveness of fossil fuels + CDR (if available) compared to alternative options (electrification, alternative fuels).	Thank you for the comment. The revised text mentions alternative fules explicitly with reference to Section 6.6.2.4.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
12025	82	27	82	28	A key limitation on CDR will be the provision and operation of adequate governance - adding this would be welcome. For Reference, see J, REYNOLDS, 2020. Elements and steps for global governance, in FLORIN, M.-V. ROUSE., P.: HUBERT, A-M.: HONEGGER, M.: REYNOLDS, J. L. 2020. International governance issues on climate engineering - Information for policymakers. International Risk Governance Centre (IRGC). Lausanne, Switzerland: EPFL Scientific Publications http's://innocence/record/277726.	Thank you for the comment. We mention climate and energy policies as germane to costs, but have no space to elaborate.	Paul Rouse	Carnegie Climate Governance Initiative (C2G) - The Carnegie Council for Ethics and International Affairs	United Kingdom (of Great Britain and Northern Ireland)
64257	82	31	83	2	OK with the following sentence reflecting a synergy between renewables and nuclear (as it is the case nowadays in many countries like France, Sweden and Finland) : “These systems could entail a mix of low-carbon generation technologies such as non-dispatchable renewables and nuclear, as well as energy storage and fossil energies with carbon removal.”	Noted. This paragraph is attempting only to describe the menu of options in the electric sector decarbonization choice set rather than to describe how they might be economic complements or substitutes, which later text describes in greater detail.	Georges VAN GOETHEM	Royal Academy of Overseas Sciences (ARSOM - KAOW)	Belgium

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
28897	82	32	82	32	http://meea.sites.luc.edu/volume20/PDFs/2.1.%20HILMI_Article_Decoupling%20Economic%20Growth%20and%20CO2%20Emissions.pdf	We appreciate the suggested citation. There are many more applicable papers than we have room to include, so we must be selective.	Nathalie Hilmi	Centre Scientifique de Monaco	France
15791	82	34	86	29	In order to strengthen my arguments below, allow me to start with some quotes from Chapter 6. [continued below]	No substantive comment included here, so no change is needed.	Jean-Michel Trochet	EDF group (French Utility)	France
15793	82	34	86	29	On pages 82-83, "systems could entail a mix of variable renewables (VRE), dispatchable renewables (e.g., biomass, hydropower), other firm dispatchable ("on-demand") low-carbon generation (e.g., nuclear, CCS-equipped capacity), energy storage, transmission, carbon removal technologies (e.g., BECCS, DAC), and demand management (…). Marginal abatement costs increase as systems approach 100 percent decarbonisation." (…) Based on their increasing economic competitiveness, VRE, especially wind and solar power, will likely comprise large shares of many regional generation mixes (…) economic and operational challenges increase nonlinearly as [VRE] shares approach 100 percent (…). Either dispatchable generation or seasonal energy storage (…) will be needed (…). Power systems require a range of different functional roles (…).a range of different types of generation, energy storage, and transmission resources may be deployed in these systems. (references, including Hirth 2015). [continued below]	This comment only quotes text, so no change is needed.	Jean-Michel Trochet	EDF group (French Utility)	France
15795	82	34	86	29	Page 85. (…) the economic value of additional wind and solar capacity typically decreases as their penetration rises due to lower resource value and integration costs, creating economic challenges at higher deployment levels (Wiser et al. (…) 100% renewable energy systems (not only the power sector) will likely not be cost-minimising solutions. [Continued below]	This comment only quotes text, so no change is needed.	Jean-Michel Trochet	EDF group (French Utility)	France
15797	82	34	86	29	Page 86. (…) studies typically assume a constrained set of available technologies to demonstrate the technical feasibility of very high renewable systems and are not optimising to find least-cost, technology-neutral decarbonisation pathways (...) . Deep decarbonisation analyses (…) often indicate large roles for VRE, but least-cost pathways for meeting emissions reduction targets rarely suggest near 100% renewables (Figure 6.22) unless optimistic assumptions about integration challenges are combined with pessimistic assumptions about alternatives (...). The 100% renewables literature assumes (implicitly or explicitly) that factors beyond cost and emissions attributes will drive portfolio selection. [Continued below]	This comment only quotes text, so no change is needed.	Jean-Michel Trochet	EDF group (French Utility)	France
15799	82	34	86	29	Page 86. "Although many studies find 100% renewable systems technically conceivable, economic and operational challenges increase nonlinearly as shares approach 100 percent (references). In addition to VRE, studies broadly agree that including additional low-, zero-, and negative-CO2 technologies – including dispatchable renewables (e.g., biomass, geothermal, hydropower), other firm dispatchable ("on-demand") low-carbon generation (e.g., nuclear, hydrogen, CCS-equipped capacity), energy storage, transmission, carbon removal technologies (e.g., BECCS, DAC), and demand management – can lower the cost of decarbonisation even with very high shares of wind and solar, but there is disagreement about the magnitude of cost savings from larger portfolios, which depends on context- and scenario-specific assumptions about technologies, markets, and policies (references including Hirth 2015)." [continued below]	This comment only quotes text, so no change is needed.	Jean-Michel Trochet	EDF group (French Utility)	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
15801	82	34	86	29	All these citations, supported by many references, lead to some major conclusions: 1) While ongoing decreasing costs of wind and solar PV (and batteries) are good news and legitimate higher shares in the electricity mix in many parts of the world, they present marginal economic values strongly decreasing with their share in the electricity. References mentioned by the report as well as present situations in the most "advanced" regions in terms of renewables developments will probably never converge towards one unique value of optimal share of REN as it highly depends, among others, on local conditions, including the quality of resource (wind and sun), the density of population for acceptability and on the local availability and costs of alternative technologies. [continued below]	It appears that the reviewer's comments agree with the written text, though there might be differences in emphasis.	Jean-Michel Trochet	EDF group (French Utility)	France
15803	82	34	86	29	2) This is also true for biomass resource (solid, liquid, gaseous), which sometimes appears to be the ultimate resource that Integrated Assessment Models (IAM) use to achieve net-zero energy systems. From my own use of the database that was provided with IPCC SR 1.5 in 2018, it appears that the total annual mitigation costs of scenarios 1.5C low overshoot, 1.5C high overshoot, Lower 2C and Higher 2C for a given year (2050 for instance) were increasing with increasing use of biomass and solar PV. [continued below]	It appears that the reviewer's comments agree with the written text, though there might be differences in emphasis.	Jean-Michel Trochet	EDF group (French Utility)	France
15805	82	34	86	29	3) The decreasing value of other technologies with their increase in the electricity mix (ceteris paribus) is not observed across models and scenarios as it is with biomass . This can mean that their variable volume use (across models and scenarios) is not large enough as causing a significant decreasing marginal value effect. This remark is independent of whether, for a given volume or share in the electricity mix, the total cost of these technologies can vary according to initial different assumptions on unit cost assumed by the different models. [continued below]	It appears that the reviewer's comments agree with the written text, though there might be differences in emphasis.	Jean-Michel Trochet	EDF group (French Utility)	France
15807	82	34	86	29	4) For just one illustration among references mentioned by the report, Hirth 2015 (The Optimal Share of Variable Renewables: How the Variability of Wind and Solar Power affects their Welfare-optimal Deployment. The Energy Journal, 36(1)) clearly shows that mitigation costs and marginal carbon abatement costs first decrease when share of VRE increases starting from a small share, but then increase when share of VRE goes beyond some threshold. [continued below]	It appears that the reviewer's comments agree with the written text, though there might be differences in emphasis.	Jean-Michel Trochet	EDF group (French Utility)	France
15809	82	34	86	29	The major conclusion of these points above is : in order to reduce the total mitigation cost to reach scenarios C1, C2 and C3 (which is important: see my remark in chapter 3), we should use the whole portfolio of decarbonised or very low carbon technologies in regions where they are affordable, available and mature today (namely, technologies recognised in other parts of chapter 6). Strategies that rely too early and too exclusively on the development of few technologies (namely solar PV, wind power and biomass) will be more costly. Strategies that avoid or hardly use dispatchable power technologies such as hydro-electricity, nuclear power and fossil-fuel with Carbon Capture and Sequestration (CCS) are poised to be "non-optimal". Non-optimal solution here is a short way to speak about the control of mitigation costs: the higher they will be, the less accepted the energy transition will be by the society.	It appears that the reviewer's comments agree with the written text, though there might be differences in emphasis.	Jean-Michel Trochet	EDF group (French Utility)	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
28425	82	34	83	2	Altough the mentioned configurations of net-zero energy emissions are maybe more likely, you could also include the potential of wind, water and solar as investigated by Jacobson [sources] Just to note that other configurations are also possible	For brevity and to give a sense for which findings in the literature are robust and which ones are more uncertain, we only include references in this sentence that are either reviews of the literature (Jenkins, et al.) or multi-model studies (Bistline, et al.; Luderer, et al.). Individual researchers/studies like Jacobson are included in the literature survey in Jenkins, et al.	Naud Loomans	Eindhoven University of Technology	Netherlands
80641	82	34	83	2	BECCS is not carbon neutral or negative in the near-term—with a carbon deficit for many years, generally several decades to a century—that is crucial for mitigating emissions and avoiding hitting the 1.5°C mark. Danielle Venton, Core Concept: Can bioenergy with carbon capture and storage make an impact?, PNAS (2016); Leturcq, P. (2020) GHG Displacement Factors of Harvested Wood Products: the Myth of Substitution, Nature Scientific Reports 10:1–9; Mary S. Booth, Not carbon neutral: Assessing the net emissions impact of residues burned for bioenergy, Environ. Res. Lett. 13 (21 February 2018); Sterman J. D., et al. (2018) Does replacing coal with wood lower CO2 emissions? Dynamic lifecycle analysis of wood bioenergy, Envtl. Research Letters 13(015007):1–10, 1 (“We simulate substitution of wood for coal in power generation, estimating the parameters governing NPP and other fluxes using data for forests in the eastern US and using published estimates for supply chain emissions. Because combustion and processing efficiencies for wood are less than coal, the immediate impact of substituting wood for coal is an increase in atmospheric CO2 relative to coal. The payback time for this carbon debt ranges from 44–104 years after clear-cut, depending on forest type—assuming the land remains forest. Surprisingly, replanting hardwood forests with fast-growing pine plantations raises the CO2 impact of wood because the equilibrium carbon density of plantations is lower than natural forests. Further, projected growth in wood harvest for bioenergy would increase atmospheric CO2 for at least a century because new carbon debt continuously exceeds NPP. Assuming biofuels are carbon neutral may worsen irreversible impacts of climate change before benefits accrue. Instead, explicit dynamic models should be used to assess the climate impacts of biofuels.”). Furthermore, even if BECCS were net zero or negative in the relevant next couple of decades, which it is not, large-scale biodiversity development requires vast land-use changes, which may have significant implications for food security and biodiversity. National Academies of Sciences, Engineering, and Medicine, Negative Emissions Technologies and Reliable Sequestration: A Research Agenda.10 (2019) (“Because	While these topics are interesting and important, space limits prevent us from addressing them here, though other sections of the chapter and report go into greater depth on these issues.	Durwood Zaelke	Institute for Governance & Sustainable Development	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
80785	82	34	83	2	BECCS is not carbon neutral or negative in the near-term—with a carbon deficit for many years, generally several decades to a century—that is crucial for mitigating emissions and avoiding hitting the 1.5°C mark. Danielle Venton, Core Concept: Can bioenergy with carbon capture and storage make an impact?, PNAS (2016); Leturcq, P. (2020) GHG Displacement Factors of Harvested Wood Products: the Myth of Substitution, Nature Scientific Reports 10:1–9; Mary S. Booth, Not carbon neutral: Assessing the net emissions impact of residues burned for bioenergy, Environ. Res. Lett. 13 (21 February 2018); Sterman J. D., et al. (2018) Does replacing coal with wood lower CO2 emissions? Dynamic lifecycle analysis of wood bioenergy, Envtl. Research Letters 13(015007):1–10, 1 ("We simulate substitution of wood for coal in power generation, estimating the parameters governing NPP and other fluxes using data for forests in the eastern US and using published estimates for supply chain emissions. Because combustion and processing efficiencies for wood are less than coal, the immediate impact of substituting wood for coal is an increase in atmospheric CO2 relative to coal. The payback time for this carbon debt ranges from 44–104 years after clear-cut, depending on forest type—assuming the land remains forest. Surprisingly, replanting hardwood forests with fast-growing pine plantations raises the CO2 impact of wood because the equilibrium carbon density of plantations is lower than natural forests. Further, projected growth in wood harvest for bioenergy would increase atmospheric CO2 for at least a century because new carbon debt continuously exceeds NPP. Assuming biofuels are carbon neutral may worsen irreversible impacts of climate change before benefits accrue. Instead, explicit dynamic models should be used to assess the climate impacts of biofuels."). Furthermore, even if BECCS were net zero or negative in the relevant next couple of decades, which it is not, large-scale biodiversity development requires vast land-use changes, which may have significant implications for food security and biodiversity. National Academies of Sciences, Engineering, and Medicine, Negative Emissions Technologies and Reliable Sequestration: A Research Agenda.10 (2019) ("Because	While these topics are interesting and important, space limits prevent us from addressing them here, though other sections of the chapter and report go into greater depth on these issues.	Gabrielle Dreyfus	Institute for Governance & Sustainable Development	United States of America
71707	82		82		Box 6.5: "Limited and targeted use of fossil fuels" is not clear enough about the need to combine any fossil fuel use with CDRs. It seems that "alternative fuels" are not defined anywhere in the text. Please consider revising!	Additional detail is provided in Section 6.6.2.1. The box is intended only as a roadmap and summary of key characteristics.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
48141	83	1	83	30	The section mentions 100% renewable energy systems but doesn't cite any papers on the subject, only papers approaching it. Please cite papers that study 100% renewable energy systems. Here are some: (1) Jacobson, M.Z., and M.A. Delucchi, A path to sustainable energy by 2030, Scientific American, November 2009; (2) Jacobson, M.Z., and M.A. Delucchi, Providing all global energy with wind, water, and solar power, Part I: Technologies, energy resources, quantities and areas of infrastructure, and materials, Energy Policy, 39, 1154-1169, doi:10.1016/j.enpol.2010.11.040, 2011; (3) Delucchi, M.Z., and M.Z. Jacobson, Providing all global energy with wind, water, and solar power, Part II: Reliability, System and Transmission Costs, and Policies, Energy Policy, 39, 1170-1190, doi:10.1016/j.enpol.2010.11.045, 2011; (4) Jacobson, M.Z., M.A. Delucchi, Z.A.F. Bauer, S.C. Goodman, W.E. Chapman, M.A. Cameron, Alphabetical: C. Bozonnat, L. Chobadi, H.A. Clonts, P. Enevoldsen, J.R. Erwin, S.N. Fobi, O.K. Goldstrom, E.M. Hennessy, J. Liu, J. Lo, C.B. Meyer, S.B. Morris, K.R. Moy, P.L. O'Neill, I. Petkov, S. Redfern, R. Schucker, M.A. Sontag, J. Wang, E. Weiner, A.S. Yachanin, 100% clean and renewable wind, water, and sunlight (WWS) all-sector energy roadmaps for 139 countries of the world, Joule, 1, 108-121, doi:10.1016/j.joule.2017.07.005, 2017; (5) Jacobson, M.Z., M.A. Delucchi, M.A. Cameron, and B.V, Mathiesen, Matching demand with supply at low cost among 139 countries within 20 world regions with 100% intermittent wind, water, and sunlight (WWS) for all purposes, Renewable Energy, 123, 236-248, 2018; (6) Jacobson, M.Z., M.A. Delucchi, M.A. Cameron, S.J. Coughlin, C. Hay, I.P. Manogaran, Y. Shu, and A.-K. von Krauland, Impacts of Green New Deal energy plans on grid stability, costs, jobs, health, and climate in 143 countries, One Earth, 1, 449-463, doi:10.1016/j.oneear.2019.12.003, 2019. Others include papers by the groups of Breyer, Mathiesen, Diessendorf, Blakers, and others.	We appreciate the suggested citations. There are many more applicable papers than we have room to include, so we must be selective. The papers you cite do not differ significantly from other papers referenced in their methods, scope, or findings to include in this passage.	Mark Jacobson	Stanford University	United States of America
10961	83	2	83	5	please add the explanation for the "a range of technologies might be cost-effective in reaching CO2 emissions targets" since it is difficult to understand the relationship between the marginal cost increase with renewables increase and the cost-effectiveness of technologies	Our available space is constrained to offer a more thorough explanation here, but we included references that help to unpack each one of these effects and their implications for power sector investments and operations under deep decarbonization.	Dong-Woon NOH	Korea Energy Economics Institute	Republic of Korea
16385	83	2	83	5	please add the explanation for the "a range of technologies might be cost-effective in reaching CO2 emissions targets" since it is difficult to understand the relationship between the marginal cost increase with renewables increase and the cost-effectiveness of technologies	Our available space is constrained to offer a more thorough explanation here, but we included references that help to unpack each one of these effects and their implications for power sector investments and operations under deep decarbonization.	Government of Republic of Korea	Korea Meteorological Administration (KMA)	Republic of Korea

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
62017	83	5	83	16	Confusion? It is not clear why the sentence changes arubtly to include everything listed at the title of Figure 6.22 in "Key factors influencing the technology mix could include relative costs and system benefits, local resource bases, infrastructure availability, regional integration and trade, co-benefits, societal preferences and other policy priorities, all of which vary by country and region (see Section 6.6.4). Many of these factors depend on when the net-zero point is reached, which can vary significantly Figure 6.22 Characteristics of global net-zero energy systems. Scenarios reaching net-zero emissions show differences in residual emissions and carbon removal (a), energy resources (b), electrification (c), energy efficiency (as measured here by energy/GDP) (d), and emissions trajectory (e), particularly with respect to warming levels (blue = <1.5˚C, green = <2.0˚C, orange = >2.0˚C). Points represent individual scenarios, with probability density distributions shown along each axis for each warming level (colors corresponding to warming levels) and for all scenarios (black). Points represent different models and scenarios from the IPCC "Global Warming of 1.5 °C" report database (Huppmann et al. 2018). Figure 6.22 panel e)."	The caption of the figure was erroneously included in the text and has been removed.	Esa Vakkilainen	LUT University, Lappeenranta	Finland
2695	83	9	83	16	reads like a Figure caption and needs improvement.	The caption of the figure was erroneously included in the text and has been removed.	Jan Wohland	ETH Zurich	Switzerland
10663	83	9	83	18	Spurious insertion of the legend of figure 6.22 here	The caption of the figure was erroneously included in the text and has been removed.	Philippe Waldteufel	CNRS	France
27733	83	9	83	9	Delete "Characteristics of global net-zero energy systems. Scenarios reaching net-zero emissions show differences in residual emissions and carbon removal (a), energy resources (b), electrification (c), energy efficiency (as measured here by energy/GDP) (d), and emissions trajectory (e), particularly with respect to warming levels (blue = <1.5°C, green = <2.0°C, orange = >2.0°C). Points represent individual scenarios, with probability density distributions shown along each axis for each warming level (colors corresponding to warming levels) and for all scenarios (black). Points represent different models and scenarios from the IPCC "Global Warming of 1.5 °C" report database (Huppmann et al. 2018). Figure 6.22 panel e).", as these describe Figure 6.22.	The caption of the figure was erroneously included in the text and has been removed.	Eleni Kaditi	Organization of the Petroleum Exporting Countries, OPEC	Austria
43609	83	9	83	16	These lines appear as a part of the main text but are presumably a caption for a figure, which is missing.	The caption of the figure was erroneously included in the text and has been removed.	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy
55811	83	9	83	16	Text is meant to be attached to a graphic, but is included in a paragraph.	The caption of the figure was erroneously included in the text and has been removed.	Government of United States of America	U.S. Department of State	United States of America
5387	83	18	83	18	add, at the end of the line : "with a strong limitation for electricity, due to the need to maintain the resilience of the grid. Most of network operators set a limit of 40% of renewable insertio onto their network, to prevent the blackout risk". This limit does not exists for thermal enrgies.	While these topics are interesting and important, space limits prevent us from addressing them here, though some of the references in this section discuss such dynamics in greater detail.	Michel SIMON	Retraité/ Pdt d'association	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
28427	83	19	83	21	"While wind and solar will likely be prominent electricity sources, this does not imply that 100% renewable energy systems will be pursued under all circumstances, since economic and operational challenges increase nonlinearly as shares approach 100 percent" The point regarding the additional costs for the last 20% has been made before and has little to do with just wind and solar, other renewable energy sources or storage could provide this baseload as well. I would rephrase this to something like. Wind and solar will likely be prominent electricity sources, but need back-up power as well. Either from seasonal storage or other renewable energy sources, or non-renewable energy sources with CC(U)S. I make this point more substantially in comment # 19	It appears that the reviewer's comments agree with the written text, though there might be differences in emphasis. Note that we discuss this in greater detail in the "100% Renewables" box.	Naud Loomans	Eindhoven University of Technology	Netherlands
78643	83	19	83	22	it shall mentioned that 100% renewable energy systems have been shown in hourly resolution and being cost effective. That's missing in the statement. Thus, suggestion: "… as shares approach 100 percent, while is has been shown that this is possible.", references for the expanded statement are: Hansen et al. (https://www.sciencedirect.com/science/article/pii/S0360544219304967), Ram et al. (http://energywatchgroup.org/wp-content/uploads/EWG_LUT_100RE_All_Sectors_Global_Report_2019.pdf) - the latter showing it for hourly resolution, high geographic detail and all sector. In further detail this is shown by Bogdanov et al. (https://www.sciencedirect.com/science/article/pii/S0306261920316639) - applying a harsh climatic environment and very high technological and sectoral detail. For electricity systems, the same is shown in very high detail by Bogdanov et al. (https://www.nature.com/articles/s41467-019-08855-1), AND showing that power system cost decline while approaching 100% renewables.	The cited text in not incompatible with the reviewer's comments. The papers cited in this sentence all vary renewable shares across a broad range and illustrate how system costs, investments, and other metrics vary. The papers cited by the reviewer do not present controlled experiments that (e.g.) vary the renewable share and illustrate how outputs of interest change for these different deployment levels (or how metrics vary based on the inclusion/exclusion of options in the choice set).	Christian Breyer	LUT University	Finland
5389	83	20	83	22	From dream to reality…. Please, add that in present state of technlogies, a system with 100% wind and solar is not a credible scenario. It makes sense only when you consider hydro and biomass renewable production.	Note that the sentence refers to future systems and not to present ones, hence possible changes in technologies, markets, and policies are anticipated.	Michel SIMON	Retraité/ Pdt d'association	France
42999	83	26	83	29	This is a strong point and should be more prominent earlier in the chapter.	While we agree about the importance of these findings, space limits prevent us from discussing all of them in greater depth in the summary material.	Kurt Kornelsen	Ontario Power Generation	Canada
78645	83	26	83	28	see the highly detailed discussion on power systems in Bogdanov et al. (https://www.nature.com/articles/s41467-019-08855-1), which applies hourly resolution, the highest known regional detail (145 regions for the world), applying various flexiiblity options, AND showing that 100% renewables leads to lower cost then the present system	Noted. The Bogdanov, et al. study includes long-duration energy storage, which aligns with the conclusion in this sentence.	Christian Breyer	LUT University	Finland
73995	83	30	83	32	it is important to mention that capacity and ancillary services can be very low energy services. Even if they are provided by dispatchable thermal generation, the emissions are relatively small in comparison to wholesale energy markets.	Noted. The references later in this paragraph discuss the relative values of services in potential future scenarios.	Heleno Miguel	Lawrence Berkeley National Laboratory	United States of America
84357	83	39	83	39	Please add the self-consumption for system control. In fact an agile management of supply and demand (for adequacy) manipulates information. According to the second principle of thermodynamics, this can be done only with spending energy which should be lower than the energy at stake for adequacy.	While these topics are interesting and important, space limits prevent us from addressing them here.	Vincent MAZAURIC	Schneider Electric	France
71709	83	43	83	44	The role of energy storage is overemphasized, in particular in comparison to the role of transmission grids, which can substantially limit the need for energy storage.	Noted. The references included here and in the high renewables box discuss the tradeoffs across different balancing options.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
78647	83	43	84	7	an optimised mix of flexibility via diurnal storage (batteries, pumped hydro), but also compressed air energy storage and seasonal storage, but also seasonal dispatch of hydropower and bioenergy is presented in much detail in Bogdanov et al. (https://www.nature.com/articles/s41467-019-08855-1) also indicating impact of climate, as it is applied for the world structured in 145 regions and calculated for energy transition pathways, cost optimisation and 100% renewables. The so far used references typically focus specific regions in the world, while in Bogdanov et al. this is done for all regions in the world, but in comparable, or even higehr level of detail as in most of the cited studies. Thus higher confidence can be obtained as a general conclusion, as this has been shown globally. In addition the variable renewables - storage - curtailment nexus has been discussed by Solomon et al. (https://www.sciencedirect.com/science/article/pii/S0306261918317756)	We appreciate the suggested citations. There are many more applicable papers than we have room to include, so we must be selective. The papers you cite do not differ significantly from other papers referenced in their methods, scope, or findings to include in this passage.	Christian Breyer	LUT University	Finland
72137	83	46	84	1	The following reference (which has received 40 citations in the last year) can be added to justify the statement "Diurnal storage options like lithium-ion batteries have different value than storing and discharging electricity over longer periods ..." M. Victoria, K. Zhu, T. Brown, G. B. Andresen, M. Greiner, The role of storage technologies throughout the decarbonisation of the sector-coupled European energy system, Energy Conversion and Management 201 (1) 111977, (2019) https://doi.org/10.1016/j.enconman.2019.111977	We appreciate the suggested citation. There are many more applicable papers than we have room to include, so we must be selective. The paper you cite does not differ significantly from other papers referenced in its methods, scope, or findings to include in this passage.	Marta Victoria	Aarhus University	Denmark
8871	84	8	84	19	Kato and Kurosawa (2021, Sustainability Science) shows the trade-offs between BECCS deployment in electricity sector and hydrogen demands to achieve the net-zero emissions energy systems.	We appreciate the suggested citation. There are many more applicable papers than we have room to include, so we must be selective. The paper you cite does not differ significantly from other papers referenced in its methods, scope, or findings to include in this passage.	Etsushi Kato	Institute of Applied Energy	Japan
60467	84	8	84	11	This sentence is incorrect. The reference Hepburn et al., 2019 discuss CCU and not CCS, so the term CCU and not CCUS should be used. But the sentence " CCUS offers opportunities for negative emissions when fueled with syngas or biomass containing carbon captured from the atmosphere". CCU can create negative emissions when CO2 is is not a message from this paper. Secondly, there is a misunderstanding on how CCU can create negative emissions. CCU, when it uses low carbon or renewable energy, can create 1) net reduction of CO2 emissions when CO2 is captured from point source and store in product whatever the duration of the storage, because of the fossil carbon substitution effect, 2) net zero emissions when CO2 from point source is e.g. sequestered in building material via mineralisation (e.g.Ostovari et al., 2020, Di Maria et al., 2020, Zevenhoven and Fagerlund, 2010, Giannoulakis et al., 2014, Cuéllar-Franca et Azapagic, 2015, Kaliyavaradhan et al., 2017, NAS, 2019, Huang et al., 2019, Lee et al., 2020, Pan et al., 2020) OR when the end of life emissions of the CO2 based product are captured again. 3) negative emissions when CO2 from Direct Air Capture is stored in building material permanently via mineralisation (Ostovari et al., 2020, SAPEA, 2018)	We use CCUS here to maintain consistency with other sections of the report.	Célia Sapart	Université Libre de Bruxelles / CO2 Value Europe	Belgium

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
76327	84	8	84	11	This sentence is incorrect. The reference Hepburn et al., 2019 discuss CCU and not CCS, so the term CCU and not CCUS should be used. But the sentence " CCUS offers opportunities for negative emissions when fueled with syngas or biomass containing carbon captured from the atmosphere". CCU can create negative emissions when CO2 is is not a message from this paper. Secondly, there is a misunderstanding on how CCU can create negative emissions. CCU, when it uses low carbon or renewable energy, can create 1) net reduction of CO2 emissions when CO2 is captured from point source and store in product whatever the duration of the storage, because of the fossil carbon substitution effect, 2) net zero emissions when CO2 from point source is e.g. sequestered in building material via mineralisation (e.g.Ostovari et al., 2020, Di Maria et al., 2020, Zevenhoven and Fagerlund, 2010, Giannoulakis et al., 2014, Cuéllar-Franca et Azapagic, 2015, Kaliyavaradhan et al., 2017, NAS, 2019, Huang et al., 2019, Lee et al., 2020, Pan et al., 2020) OR when the end of life emissions of the CO2 based product are captured again. 3) negative emissions when CO2 from Direct Air Capture is stored in building material permanently via mineralisation (Ostovari et al., 2020, SAPEA, 2018)	We use CCUS here to maintain consistency with other sections of the report.	Deepak PANT	Flemish Institute for Technological Research (VITO)	Belgium
78817	84	8	84	11	This sentence is incorrect. The reference Hepburn et al., 2019 discuss CCU and not CCS, so the term CCU and not CCUS should be used.	We use CCUS here to maintain consistency with other sections of the report.	Sylvain Nizou	CEA	France
83711	84	8	84	11	This sentence is incorrect. The reference Hepburn et al., 2019 discuss CCU and not CCS, so the term CCU and not CCUS should be used. But the sentence " CCUS offers opportunities for negative emissions when fueled with syngas or biomass containing carbon captured from the atmosphere". CCU can create negative emissions when CO2 is is not a message from this paper. Secondly, there is a misunderstanding on how CCU can create negative emissions. CCU, when it uses low carbon or renewable energy, can create 1) net reduction of CO2 emissions when CO2 is captured from point source and store in product whatever the duration of the storage, because of the fossil carbon substitution effect, 2) net zero emissions when CO2 from point source is e.g. sequestered in building material via mineralisation (e.g.Ostovari et al., 2020, Di Maria et al., 2020, Zevenhoven and Fagerlund, 2010, Giannoulakis et al., 2014, Cuéllar-Franca et Azapagic, 2015, Kaliyavaradhan et al., 2017, NAS, 2019, Huang et al., 2019, Lee et al., 2020, Pan et al., 2020) OR when the end of life emissions of the CO2 based product are captured again. 3) negative emissions when CO2 from Direct Air Capture is stored in building material permanently via mineralisation (Ostovari et al., 2020, SAPEA, 2018)	We use CCUS here to maintain consistency with other sections of the report.	Christian Breyer	LUT University	Finland
45635	84	9	84	13	The term CCUS (Carbon Capture Utilisation and Storage) is used here. This term is not clearly defined It discusses only Carbon Capture and Storage (CCS) technologies and not the utilisation phase. CSS and Carbon Capture and Use (CCU) distinctly differ regarding their CO2 reduction potential, the underlying technical processes and outcomes, their effects on climate mitigation, their business models and their environmental policy targets. Therefore, mixing CCS and CCU concepts can harm further development particularly of CCU. Therefore the term CCUS should be separated in CCS and CCU and both options should be clearly addressed independently (Cuéllar-Franca and Azapagic, 2015, J.CO2.Utili., 9, 82-102, Bruhn et al., 2016, Environmental Science & Policy, 60, 38–43, Arning et al., 2019, Energy Policy, 125, 235–249).	We use CCUS here to maintain consistency with other sections of the report.	Ana Machado	Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa	Portugal

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
60469	84	11	84	13	This statement is outdated. Numerous Life Cycle Analysis have shown the potential of CCU technologies and this is today not anymore the main barrier for the deployment of these technologies. The chances for these CCU technologies to succeed will strongly depend on the compatibility of the CO2 products with existing technology and infrastructure, with the growth and price of renewable energy and with the development of appropriate policy and market incentives (Grim et al., 2020). Despite these challenges, most of the boundary conditions (fuel composition, price, feedstock) for near- and medium-term deployment of CO2-based fuels are clear; now, it is a matter of finding the most economical route towards the synthesis of these fuels (Ramirez et al., 2020). Some examples of LCA: Kätelhön et al., 2019 suggest that the climate change mitigation potential of CCU in the chemical industry will not be dependent on the amount of CO2 used in the process, but on the potential for substitution of conventional products. From an LCA perspective, they cover the 20 most greenhouse gas intensive chemicals in Europe and conclude that the technical mitigation potential of CO2-based chemical production (i.e. technically feasible GHG reductions under full deployment of technologies) can be up to 3.5 Gt CO2-eq by 2030; The technologies are already available to switch to CO2 and water as substrates, but this would require massive amounts of renewable electricity. Thonemann and Pizzol., 2019 conducted a consequential LCA for various CCU products in the chemical industry and concluded that formic acid produced via hydrogenation and polyol production are the conversion technologies with the highest potential for reducing the global warming impact from a life cycle perspective. Interestingly, they claim that for long-term scenarios where CO2 demand will increase and will be covered from dilute sources, the global warming potential of CCU will increase due to higher intensities related to capture. Therefore, they suggest not to postpone CCU technologies deployment for later. Ostovari et al., 2020 have shown that all considered CCU technologies for mineralization could reduce climate impacts over the	The reviewer notes the "potential" here, acknowledging (as the quoted text does) that there are uncertainties moving forward, though the potential role is clear.	Célia Sapart	Université Libre de Bruxelles / CO2 Value Europe	Belgium

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
76329	84	11	84	13	This statement is outdated. Numerous Life Cycle Analysis have shown the potential of CCU technologies and this is today not anymore the main barrier for the deployment of these technologies. The chances for these CCU technologies to succeed will strongly depend on the compatibility of the CO2 products with existing technology and infrastructure, with the growth and price of renewable energy and with the development of appropriate policy and market incentives (Grim et al., 2020). Despite these challenges, most of the boundary conditions (fuel composition, price, feedstock) for near- and medium-term deployment of CO2-based fuels are clear; now, it is a matter of finding the most economical route towards the synthesis of these fuels (Ramirez et al., 2020). Some examples of LCA: Kätelhön et al., 2019 suggest that the climate change mitigation potential of CCU in the chemical industry will not be dependent on the amount of CO2 used in the process, but on the potential for substitution of conventional products. From an LCA perspective, they cover the 20 most greenhouse gas intensive chemicals in Europe and conclude that the technical mitigation potential of CO2-based chemical production (i.e. technically feasible GHG reductions under full deployment of technologies) can be up to 3.5 Gt CO2-eq by 2030; The technologies are already available to switch to CO2 and water as substrates, but this would require massive amounts of renewable electricity. Thonemann and Pizzol., 2019 conducted a consequential LCA for various CCU products in the chemical industry and concluded that formic acid produced via hydrogenation and polyol production are the conversion technologies with the highest potential for reducing the global warming impact from a life cycle perspective. Interestingly, they claim that for long-term scenarios where CO2 demand will increase and will be covered from dilute sources, the global warming potential of CCU will increase due to higher intensities related to capture. Therefore, they suggest not to postpone CCU technologies deployment for later. Ostovari et al., 2020 have shown that all considered CCU technologies for mineralization could reduce climate impacts over the	The reviewer notes the "potential" here, acknowledging (as the quoted text does) that there are uncertainties moving forward, though the potential role is clear.	Deepak PANT	Flemish Institute for Technological Research (VITO)	Belgium

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
83713	84	11	84	13	This statement is outdated. Numerous Life Cycle Analysis have shown the potential of CCU technologies and this is today not anymore the main barrier for the deployment of these technologies. The chances for these CCU technologies to succeed will strongly depend on the compatibility of the CO2 products with existing technology and infrastructure, with the growth and price of renewable energy and with the development of appropriate policy and market incentives (Grim et al., 2020). Despite these challenges, most of the boundary conditions (fuel composition, price, feedstock) for near- and medium-term deployment of CO2-based fuels are clear; now, it is a matter of finding the most economical route towards the synthesis of these fuels (Ramirez et al., 2020). Some examples of LCA: Kätelhön et al., 2019 suggest that the climate change mitigation potential of CCU in the chemical industry will not be dependent on the amount of CO2 used in the process, but on the potential for substitution of conventional products. From an LCA perspective, they cover the 20 most greenhouse gas intensive chemicals in Europe and conclude that the technical mitigation potential of CO2-based chemical production (i.e. technically feasible GHG reductions under full deployment of technologies) can be up to 3.5 Gt CO2-eq by 2030; The technologies are already available to switch to CO2 and water as substrates, but this would require massive amounts of renewable electricity. Thonemann and Pizzol., 2019 conducted a consequential LCA for various CCU products in the chemical industry and concluded that formic acid produced via hydrogenation and polyol production are the conversion technologies with the highest potential for reducing the global warming impact from a life cycle perspective. Interestingly, they claim that for long-term scenarios where CO2 demand will increase and will be covered from dilute sources, the global warming potential of CCU will increase due to higher intensities related to capture. Therefore, they suggest not to postpone CCU technologies deployment for later. Ostovari et al., 2020 have shown that all considered CCU technologies for mineralization could reduce climate impacts over the	The reviewer notes the "potential" here, acknowledging (as the quoted text does) that there are uncertainties moving forward, though the potential role is clear.	Christian Breyer	LUT University	Finland
2881	84	12	84	14	What are the impacts of the increased bioenergy production for BECCS in terms of land use? Can BECCS be scaled up sustainably? It woud be useful to have some comments on these issues in the chapter	Other sections of the chapter go into greater detail regarding cobenefits and other environmental implications of different technological options, so no detailed discussion is provided here (though some of the cited references discuss these subjects).	Leonardo Barreto	Head of center "EU&International"	Austria
18257	84	13	84	15	(Section 6.6.2.2) Whether or not BECCS is a truly zero or negative emissions technology is still very much debated and depends (for example) on how upstream emissions from land use change and ecosystem impacts are accounted for. It is therefore potentially misleading to state "...negative emissions technologies like BECCS.." without reference to lack of agreement / confidence in such a statement. Could the authors please condier revising to reflect this uncertainty?	Other sections of the chapter go into greater detail regarding cobenefits and other environmental implications of different technological options, so no detailed discussion is provided here (though some of the cited references discuss these subjects).	Government of United Kingdom (of Great Britain and Northern Ireland)	Department for Business, Energy & Industrial Strategy	United Kingdom (of Great Britain and Northern Ireland)
72139	84	17	84	19	The following reference is very relevant and it can be added to justify the following statement "If DAC technologies are used, electricity and heat requirements to operate DAC could impact power system investments and operations. " Creutzig, F., Breyer, C., Hilaire, J., Minx, J., Peters, G.P., and Socolow, R. (2019). The mutual dependence of negative emission technologies and energy systems. Energy Environ. Sci. 12, 1805–1817.	We added an additional reference to this sentence.	Marta Victoria	Aarhus University	Denmark

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
78649	84	17	84	19	suggestion to expand the statement: ".. Investments and operations, while this may be within an acceptable range." - the extension is based on the findings in Breyer et al. (https://www.cell.com/joule/fulltext/S2542-4351(19)30413-1) and Ram et al. (http://energywatchgroup.org/wp-content/uploads/EWG_LUT_100RE_All_Sectors_Global_Report_2019.pdf ; scenario is available in AR6 scenarios database) and a recent report of the German Energy Agency (https://www.powerfuels.org/fileadmin/powerfuels.org/Dokumente/Global_Alliance_Powerfuels_Study_Powerfuels_in_a_Renewable_Energy_World.pdf), where DAC is the prime source for carbon as a raw material for zero GHG emission energy-industry systems, AND the associated energy demand has been found to be NOT highly relevant.	We added an additional reference to this sentence.	Christian Breyer	LUT University	Finland
70153	84	19			(Realmonte et al. 2019). The energy requirements for the fans alone in removing 1GtCO2 could be as high as 81 kWh/tCO2 (more than all the solar power generation in the U.S. in 2017) (Fridley and Heinberg, 2018; Keith et al., 2018). This high energy use requirement also translates to large areas of land being devoted to energy generation. For the capture of 1 GtCO2 using liquid solvent DAC systems powered by natural gas, would require a land area more than five times the size of the city of Los Angeles. If instead, solar is used to power the DAC systems, the land area required expands to more than ten times the size of the state of Delaware (NAS, 2019 ; Sekera & Lichtenberger, 2020). https://www.renewableenergyworld.com/wind-power/can-climate-change-be-stopped-by-turning-air-into-gasoline/ ; https://www.sciencedirect.com/science/article/pii/S2542435118302253 ; https://cmi.princeton.edu/wp-content/uploads/2019/12/Pacala-NAS-study-2019.pdf ; https://link.springer.com/article/10.1007/s41247-020-00080-5	We added an additional reference to this sentence.	Rayner Andersen	Department of Fisheries and Oceans	Canada
28429	84	20	84	25	Not just detailed regional planning models are required. When getting to regional implementation of renewable energy sources also more detailed socio-technical energy transition (STET) models. are requried including social factors to change, market mechanisms, feedback loops and tipping points (Li, Trutnevyte & Strachan, 2015) https://doi.org/10.1016/j.techfore.2015.07.017	While these topics are interesting and important, space limits prevent us from addressing them here.	Naud Loomans	Eindhoven University of Technology	Netherlands
72141	84	22	84	25	The following reference is very relevant to support that statement since it provides a detailed comparison between the solar penetration in results produced by IAMs and included in the IPCC 5thAR and the 1.5ºC Global Warming Special Report and those results produced with models including high spatial and temporal resolution. It proves the extreme importance of using high resolution to capture the mitigation potential of solar PV and it argues that this is one of the main reasons behind the underestimation of solar PV in previous IPCC reports (5th AR and 1.5ºC Special report) M. Victoria, N. Haegel, I. M. Peters, R Sinton, A. Jäger-Waldau, C. Cañizo, C. Breyer, M. Stocks, A. Blakers, I. Kaizuka, K. Komoto, A. Smets, Solar photovoltaics is ready to power a sustainable future, Joule (2021)	We added a reference to this paper in this passage.	Marta Victoria	Aarhus University	Denmark

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
28431	84	27	86	29	This Box 6.6. in particular, but the entire subchapter on net-zero energy systems more genaral, is fairly negative on the potential of 100% renewable energy systems. One often mentioned source is Jenkins et al. 2018. This is a good study but does not take large-scale long-term hydrogen storage into account. This would be one of the enabling technologies towards such an 100% RE system. In more general terms a lot of studies show the potential of 100% RE systems based on storage, sector coupling, e-fuels and bio-energy to abate the hardest sectors as well. Hansen, Breyer and Lund (2019) give a more balanced over in their paper: "One final priority concerns the feasibility of future 100% RE systems for various regions. Most studies find that it is technically probable to carry out a 100% RE transition (at least in certain sectors), but less consistency exists regarding the economic feasibility of this transition. In some studies, authors argue that it will be extremely costly (and technically infeasible) to perform this 100% RE transition [75,207,208], while other researchers find that it is both technically and economically feasible [143,145,150,224,227]. " See DOI: https://doi.org/10.1016/j.energy.2019.03.092. For a better overview, studies by the groups of Lund and Mathiesen using the EnergyPLAN model, Jacobson (Stanford), Breyer (Lappeenranta University of Technology), Brown & Schlachtberger (KIT) are excelent examples of 100% RE studies. Some references are DOI: https://doi.org/10.1016/j.apenergy.2020.116273 https://doi.org/10.1016/j.energy.2008.04.003 , https://doi.org/10.1016/j.apenergy.2010.03.001 and https://doi.org/10.1016/j.apenergy.2010.03.006. DOI:10.1016/j.energy.2018.06.222 DOI: 10.1016/j.futures.2020.102644 https://doi.org/10.1007/s11027-019-9847-y https://doi.org/10.1016/j.egypro.2014.01.154	Note that Jenkins, et al. (2018b) receives citations in part due to the fact that it is a review paper. In other instances, we have used reviews and multi-model studies (as opposed to individual studies) to give a broader sense of what the literature says in terms of robust insights and areas of disagreement. Included there is the Hansen, et al. (2019) review.	Naud Loomans	Eindhoven University of Technology	Netherlands
55813	84	27	86	29	This is very repetitive and could be shortened or summarized to read more concisely.	Noted. This box was revised for clarity and to add updated references.	Government of United States of America	U.S. Department of State	United States of America
66715	84	27	86	29	Box 6.6. I find the contents of this box not fully consistent with its title. Referring to 100% renewables means also discussing how such target will impact the heating and the transport sectors. Here the discussion is solely/largely on challenges for the power sector of integrating such large shares of renewables.	The contents of the box are consistent with the title "100% Renewables in Net-Zero Energy Systems". The box does include a discussion of sector coupling and demand management, though space constraints mean that some of the heavy lifting must done with the citations.	Chiodi Alessandro	E4SMA	Italy
78653	84	27	86	29	It is highly shocking that in the entire box the argument of opponetns of 100% renewables are ventilated much, but almost NO articles are cited from the three leading teams in the world in 100% renewables research (according to articles and citations). This indicates a strong bias against 100% renewables in the entire box and HAS TO BE fixed. The three leading teams accroding to articles and citations are Lund/Mathiesen (Aalborg), Breyer (LUT) and Jacobson (Stanford), while only one article of Jacobson, two common article of Lund/Mathiesen/Breyer are cited, however a long list of debatable articles of highly renewable critiques, which are partly outdated, or proven biased. A detailed major revision of the entire box and more balanced presentation of results is required.	Note that the researchers mentioned by the reviewer are cited in this box and in other nearby sections. In some instances, these citations come through review articles that are referenced in the box (the Hansen, et al. (2019) review is an important one in this respect), and in other instances, the reviewers are included in the "et al." but are not the first authors.	Christian Breyer	LUT University	Finland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
78667	84	27	86	29	several key benefits of 100% renewables systems are missing in the text box, which further strengthens the claim of a biased handling of this entire, and very important text box. What's missing: energy security has been found to be increased in 100% renewable systems (https://www.mdpi.com/2071-1050/12/12/4921); the jobs situation is improved in 100% renewables systems (https://www.sciencedirect.com/science/article/pii/S0040162518314112; https://www.sciencedirect.com/science/article/pii/S2590332219302258); air pollution is decreased in 100% renewables systems (https://www.sciencedirect.com/science/article/pii/S2590332219302258), and water stress is decreased in 100% renwables systems (https://www.nature.com/articles/s41560-019-0501-4). All these co-benefits are ignored in the entire text box and shall be added for a more balanced overview on existing literature, which shall be the idea of the entire AR6 - condensed overview on existing literature.	While these topics are interesting and important, space limits prevent us from addressing them here. The first sentence mentions some of these broader benefits, and other sections of the chapter go into greater depth with these topics.	Christian Breyer	LUT University	Finland
83931	84	27	84	29	First, 100% RE is not 100% VRE. Thus, I don't understand why this document tries to view 100% RE as 100% VRE. With my definition, I expect several integrated regions that can run on 100% RE for full energy systems without need of seasonal storage. They simply need to be a bit smarter in designing and operating their system to allow complementarity of various RE resource as long as they can provide 15% of the total electricity (including all sectors) need from non-VRE source. Thus, I did not find any plausible proof in your document in support of your views stated in this chapter as it relates to this. Second, even though that is rarely necessary, I also believe that 100% VRE can also be technically and economically be feasible based on the present knowledge. But I also recognize that this entails very high uncertainty as compared to the 100% RE. It is only in this case that seasonal storage will be needed. I don't believe that your statement in this section follows the facts in present scientific knowledge. Please see my short summarised of how system should evolve as RE increases. To correctly understand the challenge of integrating large VRE, modelling techniques should have the ability to match the VRE output to the demand throughout the year among other things. Systematic studies that have tried to address such gaps have shown important lessons about building a power system with a large VRE shares. Some of the key lessons includes: (i) VRE penetration of up to 90% could be achieved with storage capacity lower than daily average demand [1-5]; (ii) storage design should be aimed at optimizing its use to increase seasonal and diurnal matching of the VRE output [1-7]; (iii) Conventional balancing capacity need significantly decreases as VRE penetration increases [1,3,7], in contradiction with the widely held views that conventional balancing need increases; (iv) Curtailment, storage and penetration should simultaneously increase under an optimally designed system as opposed to the view that presence of storage can remove the need for curtailment [3-5]; (v) Curtailment-storage-penetration nexus defines the suitability of specific storage	The box includes discussions of all renewables as the second sentence suggests. However, wind and solar do receive greater emphasis in the box owing to their extensive cost reductions and projections for their greater role moving forward. We appreciate the suggested citations, too. There are many more applicable papers than we have room to include, so we must be selective. The papers you cite do not differ significantly from other papers referenced in their methods, scope, or findings to include in this passage.	Solomon Asfaw	LUT University	Finland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
85477	84	27	86	29	To me box 6.6 is pretty negative about 100% renewable energy while there are now about 400 articles that show this is possible with batteries and seasonal storage in most countries (although often not spatially detailed and not providing pathways). I think it would be strange not to mention trailblazers like Mark Z Jacobson, Christian Breyer and Tom Brown here. E.g. https://doi.org/10.1016/j.egypro.2014.01.154 https://doi.org/10.1016/j.apenergy.2020.116273 https://doi.org/10.1016/j.energy.2008.04.003 https://doi.org/10.1016/j.apenergy.2010.03.001 https://doi.org/10.1016/j.apenergy.2010.03.006. https://doi.org/10.1007/s11027-019-9847-y	The researchers mentioned by the reviewer are cited in this box and in other nearby sections. In some instances, these citations come through review articles that are referenced in the box (the Hansen, et al. (2019) review is an important one in this respect), and in other instances, the reviewers are included in the "et al." but are not the first authors.	Auke Hoekstra	Eindhoven University of Technology	Netherlands
80643	84	30	84	31	Bioenergy should not be included as renewable, since harvesting results in a carbon deficit for many years, generally several decades to a century—that is crucial for mitigating emissions and avoiding hitting the 1.5°C mark. Danielle Venton, Core Concept: Can bioenergy with carbon capture and storage make an impact?, PNAS (2016); Leturcq, P. (2020) GHG Displacement Factors of Harvested Wood Products: the Myth of Substitution, Nature Scientific Reports 10:1–9; Mary S. Booth, Not carbon neutral: Assessing the net emissions impact of residues burned for bioenergy, Environ. Res. Lett. 13 (21 February 2018); Sterman J. D., et al. (2018) Does replacing coal with wood lower CO2 emissions? Dynamic lifecycle analysis of wood bioenergy, Envtl. Research Letters 13(015007):1–10, 1 (“We simulate substitution of wood for coal in power generation, estimating the parameters governing NPP and other fluxes using data for forests in the eastern US and using published estimates for supply chain emissions. Because combustion and processing efficiencies for wood are less than coal, the immediate impact of substituting wood for coal is an increase in atmospheric CO2 relative to coal. The payback time for this carbon debt ranges from 44–104 years after clear-cut, depending on forest type—assuming the land remains forest. Surprisingly, replanting hardwood forests with fast-growing pine plantations raises the CO2 impact of wood because the equilibrium carbon density of plantations is lower than natural forests. Further, projected growth in wood harvest for bioenergy would increase atmospheric CO2 for at least a century because new carbon debt continuously exceeds NPP. Assuming biofuels are carbon neutral may worsen irreversible impacts of climate change before benefits accrue. Instead, explicit dynamic models should be used to assess the climate impacts of biofuels.”). Furthermore, even if BECCS were net zero or negative in the relevant next couple of decades, which it is not, large-scale biodiversity development requires vast land-use changes, which may have significant implications for food security and biodiversity. National Academies of Sciences, Engineering, and Medicine, Negative Emissions Technologies and Reliable Sequestration: A Research Agenda.10 (2019) (“Because	We changed the phrasing here to "Renewables could include…" to acknowledge the controversy surrounding definitions of which technologies count as renewable.	Durwood Zaelke	Institute for Governance & Sustainable Development	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
80787	84	30	84	31	Bioenergy should not be included as renewable, since harvesting results in a carbon deficit for many years, generally several decades to a century—that is crucial for mitigating emissions and avoiding hitting the 1.5°C mark. Danielle Venton, Core Concept: Can bioenergy with carbon capture and storage make an impact?, PNAS (2016); Leturcq, P. (2020) GHG Displacement Factors of Harvested Wood Products: the Myth of Substitution, Nature Scientific Reports 10:1–9; Mary S. Booth, Not carbon neutral: Assessing the net emissions impact of residues burned for bioenergy, Environ. Res. Lett. 13 (21 February 2018); Sterman J. D., et al. (2018) Does replacing coal with wood lower CO2 emissions? Dynamic lifecycle analysis of wood bioenergy, Envtl. Research Letters 13(015007):1–10, 1 (“We simulate substitution of wood for coal in power generation, estimating the parameters governing NPP and other fluxes using data for forests in the eastern US and using published estimates for supply chain emissions. Because combustion and processing efficiencies for wood are less than coal, the immediate impact of substituting wood for coal is an increase in atmospheric CO2 relative to coal. The payback time for this carbon debt ranges from 44–104 years after clear-cut, depending on forest type—assuming the land remains forest. Surprisingly, replanting hardwood forests with fast-growing pine plantations raises the CO2 impact of wood because the equilibrium carbon density of plantations is lower than natural forests. Further, projected growth in wood harvest for bioenergy would increase atmospheric CO2 for at least a century because new carbon debt continuously exceeds NPP. Assuming biofuels are carbon neutral may worsen irreversible impacts of climate change before benefits accrue. Instead, explicit dynamic models should be used to assess the climate impacts of biofuels.”). Furthermore, even if BECCS were net zero or negative in the relevant next couple of decades, which it is not, large-scale biodiversity development requires vast land-use changes, which may have significant implications for food security and biodiversity. National Academies of Sciences, Engineering, and Medicine, Negative Emissions Technologies and Reliable Sequestration: A Research Agenda 10 (2019) (“Because	We changed the phrasing here to "Renewables could include…" to acknowledge the controversy surrounding definitions of which technologies count as renewable.	Gabrielle Dreyfus	Institute for Governance & Sustainable Development	United States of America
5391	84	32	85	2	The recent study (January 2021) by RTE and IEA has clearly established that scenarios 100 % renewable electricity may be considered only if 4 key and cumulatives conditions (tehnical, economical, and social) were met, and that as of to day, solutions to overcome these conditions are not known. As a conclusion, it is considered that the objective of 100% renewable with a high part of wind and solar (>40%) is unrealistic.	We appreciate the suggested citation. There are many more applicable papers than we have room to include, so we must be selective. The paper you cite does not differ significantly from other papers referenced in its methods, scope, or findings to include in this passage.	Michel SIMON	Retraité/ Pdt d'association	France
9821	84	32	84	35	The statement only focuses on wind and solar based electricity generation sector while the net-zero energy system, as introduced in Section 6.6, covers not only electricity generation sector but also other energy use sectors as well. Therefore, need to rewrite the paragraph in the theme of "net-zero electricity production system".	The box includes discusses of all renewables as the second sentence suggests. However, wind and solar do receive greater emphasis in the box owing to their extensive cost reductions and projections for their greater role moving forward.	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
17431	84	33	84	35	"..it is technically feasible to use very high renewables shares (e.g., above 75% of annual regional generation) to meet hourly electricity demand under a range of conditions." Possible with hydro. Probably not possible with wind and solar only for reasonable price. Reference needed. (Reference needed also for 100% RE).	Hydro is included here as a renewable technology (as described in the second sentence of the box). More detailed references are provided later in this paragraph.	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
45515	84	33	84	34	I assume that this should be "high variable renewable shares"? (high renewable shares in general is not so difficult)	We are including all renewables (per the second sentence of the box) in this statement, though wind and solar are likely to be large shares in many instances.	Kornelis Blok	Delft University of Technology	Netherlands

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
78531	84	33	84	35	"..it is technically feasible to use very high renewables shares (e.g., above 75% of annual regional generation) to meet hourly electricity demand under a range of conditions." Possible with large share of hydro. Probably not possible with wind and solar only for reasonable price. Reference needed. Should be clear diferentation between VRE (variable renewable sources like wind and solar) and other RES (like hydro and biomass).	Hydro is included here as a renewable technology (as described in the second sentence of the box). More detailed references are provided later in this paragraph.	Tomaž Žagar	Faculty for Energy Technology, University of Maribor	Slovenia
82311	84	33	84	45	Several countries already have close to 100% renewable share in the electricity mix (e.g. Costa Rica, Norway and Sweden). I assume that you here mean intermittent renewables. If this is the case, I suggest to add intermittent to all renewables when appropriate, e.g. on row 33-34: "… to use a very high intermittent renewables shares…"	Hydro is included here as a renewable technology (as described in the second sentence of the box). More detailed references are provided later in this paragraph.	Anna Krook-Riekkola	Luleå University of Technology	Sweden
10963	84	38	84	38	delete ")" in low-carbon power systems)".	This typo was corrected.	Dong-Woon NOH	Korea Energy Economics Institute	Republic of Korea
16387	84	38	84	38	delete ")" in low-carbon power systems)".	This typo was corrected.	Government of Republic of Korea	Korea Meteorological Administration (KMA)	Republic of Korea
78651	84	41	84	44	references are not balanced for that statement, as intentional curtailment is partly exaggerated in the chosen references, and much lower in not used references. This imbalance shall be fixed, in also using references which do high resolution studies (technology-rich, hourly, regional variation), as limited technology portfolio and limited cost optimisation can strongly distort results. References carrying out such studies, or reviewing it in a balanced way are: Brown et al. https://www.sciencedirect.com/science/article/pii/S1364032118303307, Bogdanov et al. (https://www.nature.com/articles/s41467-019-08855-1) and Child et al. https://www.sciencedirect.com/science/article/pii/S0960148119302319	We added two recent review articles to support this statement.	Christian Breyer	LUT University	Finland
69641	84	43	85	7	The concept of "energy storage", even if limited to relations with electricity, also includes storage before electricity is generated (e.g. in hydropower reservoir dams, in thermal storage of CSP plants), and storage on the demand side, such as thermal storage in industry (technologies delivering continuous superheated air or steam based on variable electricity generation: Siemens ET, Lumenion, Rondo...) or commercial and domestic applications (cold storage as chilled water or ice-water change in refrigeration and air-conditionning systems, heat storage in water boilers, ground rocks or water tables, etc.).	These technologies are covered in the references though are not called out specifically due to space constraints.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
72143	84	44	84	44	The following reference (with more than 200 citations already) must be included as it set the state-of-the-art of how to properly include storage, curtailmente, transmission and all the existing balancing mechanisms in highly renewable energy systems. Brown, T., Schlachtberger, D., Kies, A., Schramm, S., and Greiner, M. (2018). Synergies of sector coupling and transmission reinforcement in a cost-optimised, highly renewable European energy system. Energy 160, 720–739.	We added two recent review articles to support this statement. The Brown, et al. paper is included in a nearby sentence.	Marta Victoria	Aarhus University	Denmark
78655	84	44	85	2	the article with the second most articles to 100% renewable and much discussion, in particular also refering standard myth is Brown et al. https://www.sciencedirect.com/science/article/pii/S1364032118303307, which is not cited, but shall be added for a proper discussion	We appreciate the suggested citations. There are many more applicable papers than we have room to include, so we must be selective. The papers you cite do not differ significantly from other papers referenced in their methods, scope, or findings to include in this passage.	Christian Breyer	LUT University	Finland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
4835	85	3	85	3	3 (third bullet): “flexible nuclear” (Jenkins et al. 2018a). In this way actual ‘inflexible’ nuclear power has transited over ‘relatively inflexible’ to ‘flexible’. Science is more precise. For example, it is necessary to clarify the impact of the ageing world nuclear reactor fleet (average age above 30 years) on the availability, reliability and flexibility of the reactors (in 2018, the load factor of the Belgian nuclear park was but 50%; in 2019, maintenance outages in France were 44% longer than anticipated at the beginning of the outage).	This statement does not assess the likelihood that any particular option is part of the deployed mix but rather enumerates possibilities in the low-carbon choice set. Unfortuantely, space constraints limit our ability to discuss any of these options here in greater depth, though other parts of the chapter do include such discussions.	Aviel Verbruggen	University of Antwerp	Belgium
17433	85	3	85	3	" Energy storage technologies like batteries, pumped hydro, and hydrogen…" Hydrogen and batteries are negligible in comparison with pumped hydro. Thus reformulation of the sentence is recommended.	Note that this box (and section of the chapter as a whole) focus on future systems, which may be very different from current one.	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
43611	85	3	85	4	An example of sector coupling may help readers understand the idea here. Note that there something wrong with line numbering on this page	Space constraints limit our ability to go into greater depth here, hence the references to other sections of the chatper.	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy
51403	85	3			Box 6.6 Dispatchable… : ... or flexible nuclear (Jenkins et al. 2018a); or gas turbines fuelled by green hydrogen.	We added "or hydrogen" to this sentence.	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
51405	85	3			see https://www.ge.com/power/gas/fuel-capability/hydrogen-fueled-gas-turbines	We added "or hydrogen" to this sentence.	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
62019	85	3	85	4	Typo (problem with line numbers in original) change reference in line "2019; Pleßmann and Blechinger 2017; Macdonald et al. 2016; Mai and Et al 2014) and " to reflect correct use of et al. (see also to correct reference in page 170) to "2019; Pleßmann and Blechinger 2017; Macdonald et al. 2016; Mai et al. 2014) and"	This typo was corrected.	Esa Vakkilainen	LUT University, Lappeenranta	Finland
69645	85	3	85	3	The concept of "energy storage", even if limited to relations with electricity, also includes storage before electricity is generated (e.g. in hydropower reservoir dams, in thermal storage of CSP plants), and storage on the demand side, such as thermal storage in industry (technologies delivering continuous superheated air or steam based on variable electricity generation: Siemens ET, Lumenion, Rondo...) or commercial and domestic applications (cold storage as chilled water or ice-water change in refrigeration and air-conditionning systems, heat storage in water boilers, ground rocks or water tables, etc.).	These technologies are covered in the references though are not called out specifically due to space constraints.	Cédric PHILIBERT	Institut Français des Relations Internationales	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
69647	85	3	85	3	The area that offers the most important way to integrate very large shares of variable renewables in the energy mix of the power systems and in the broader energy mix is only give one sentence here. It should be underlined here that the electrification of transports, buildings and industry, notably with battery electric vehicles, with compact high-temperature heat storage for industry, with heat and cold storages for building application, and with production of green hydrogen, if only for chemicals, steel making, aviation and shipping, will, if well managed,allows to finance a large expansion of variable renewable assets while not contributing to the demand at peak hours, thereby reducing the volumes of dispatchable electricity generation required to ensure electricity security and face, in particular, "dark doldrums", i.e. extended periods (up to a couple of weeks) with low sunshine and low winds.	Space constraints limit our ability to go into greater depth here, hence the references to other sections of the chatper.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
72145	85	3	85	3	The following reference (with more than 200 citations already) must be included to support the statement "To balance differences in resource availability, studies of high renewable systems also typically entail investments in transmission capacity" Brown, T., Schlachtberger, D., Kies, A., Schramm, S., and Greiner, M. (2018). Synergies of sector coupling and transmission reinforcement in a cost-optimised, highly renewable European energy system. Energy 160, 720–739.	Brown, et al. (2018) is included in the references.	Marta Victoria	Aarhus University	Denmark
77391	85	3	85	4	Under "Energy storage" reservoir hydropower should also be mentioned. It is also strange to see that Lithium-Ion batteries are mentioned. They play a very minor role in electricity system storage.	Space constraints limit our ability to go into greater depth here, hence the references to other sections of the chatper.	Atle Harby	SINTEF Energy Research	Norway
78657	85	3	85	3	suggestion for adjustment: "… or seasonal storage, which in total can lead to lower cost electricity supply as of today." - exactly that's the fundamental conclusion of Bogdanov et al. (https://www.nature.com/articles/s41467-019-08855-1) in high technological, temporal and geospatial detail.	We appreciate the suggested citation. There are many more applicable papers than we have room to include, so we must be selective. The paper you cite does not differ significantly from other papers referenced in its methods, scope, or findings to include in this passage.	Christian Breyer	LUT University	Finland
78659	85	3	85	3	for the part at 'dispatchable' it would be very helpful to add to the part 'renewables like hydropower, geothermal, or biomass' the reference Bogdanov et al. (https://www.nature.com/articles/s41467-019-08855-1), as there it has been studied in much detail in hourly resolution and globally for 145 regions, while the used reference is much more restricted in scope and analyses	We included a reference to the Hansen, et al. (2019) review here.	Christian Breyer	LUT University	Finland
78661	85	3	85	3	for the part at 'demand management' it would be very helpful to add to the part 'sector coupling' the reference Bogdanov et al. (https://www.sciencedirect.com/science/article/pii/S0306261920316639, as there it has been studied in much detail in hourly resolution for a step by step approach in sector coupling starting with the power sector and then adding step by step heat, transport, industry and desalination and focus sector coupling effects in much detail.	We agree that sector coupling is an important part of the studies. But space constraints limit our ability to go into greater depth here, hence the references to other sections of the chatper.	Christian Breyer	LUT University	Finland
82313	85	3	85	3	Energy Storage It is becoming more and more obvious that we need to separate between seasonal and daily/weekly storage. There are several options for daily/weekly storage (batteries, pump-hydro, demand-response etc), while there are few seasonal storage options. Please, make a difference between the two in this section.	Noted.	Anna Krook-Riekkola	Luleå University of Technology	Sweden

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
82315	85	3	85	3	Sector coupling. I have two concerns: • For some countries, thermal energy (e.g. district heating) may be an important enabler in the power balancing. This is pointed out in Section 6.4.3 (see e.g. Figure 6.17). And is already doing so in Denmark. Please add this to the text! (power-to-x may be an option in the future, but will depend on the price differences on the power markets and the cost of storage of the "x"/fuel being produced). • I don't understand how an increased end-use electrification could work as a balancing options. An increase of electrification of space heating can make the season balancing worse.	Space constraints limit our ability to go into greater depth here, hence the references to other sections of the chatper, including to a nice Brown, et al. paper that illustrates how the impact of electrification on renewables depends on assumptions about flexibility.	Anna Krook-Riekkola	Luleå University of Technology	Sweden
85461	85	3	85	3	"Lithium-ion batteries have received attention as costs fall and installations increase, but very high renewable shares typically entail either dispatchable generation or seasonal storage." This creates the impression that it's a choice between seasonal storage or batteries. This is not correct: batteries are best suited for storage that is cycled often (often simplified into the term "daily storage" because that cycle dominates this use case) while a yearly cycle with batteries is completely unrealistic. That's where seasonal storage comes in. That term is not yet explained in box 6.6 so I propose to add it here. All in all I would propose changing the formulation slightly to e.g.: "Lithium-ion batteries have received attention as costs fall and installions increase. They are indeed well suited to offer short term and daily stabilization for fully renewable systems. However, to cover seasonal fluctuations in a fully renewable system, additional measures are needed. One options is seasonal storage in the form of a fuel that is produced with solar or wind. Typical options are hydrogen from electrolysis and bioenergy. Another option is dispatchable generation (Arbabzadah ..."	We added "in addition to short-duration" options to this sentence.	Auke Hoekstra	Eindhoven University of Technology	Netherlands
85463	85	3	85	3	There is an overlap between storage and dispatchable generation. Jesse Jenkins is best know for using this term for arguing we need something like nuclear (although that argument is less prominent since he moved from MIT to Harvard) but basically the difference between storage and dispatchable of firm generation is conceptual and can be provided in practise by the same energy sources. Anyway, I would maybe simply let it stand but add synfuel (e.g. hydrogen) to the list. A good overview publication as reference is Blanco and Faaij 2018 http://dx.doi.org/10.1016/j.rser.2017.07.062 hydrogen to the list. The following formulation could make the paragraph complete in my opinion: "Dispatchable generation could include flexible fossil units with lower minimum load levels (Bistline et al. 2019; Denholm et al. 2018); renewables like hydropower, geothermal, or biomass (Hirth 2016); fuel produced with renewable electricity (Faajij 2018); or flexible nuclear (Jenkins et al. 2018a)."	Good point. We added low-carbon hydrogen to this list.	Auke Hoekstra	Eindhoven University of Technology	Netherlands
17531	85	4	85	4	Just to note that sector coupling is also mentioned under Demand management bullet point and in a stand-alone point	We removed "sector coupling" from this sentence.	Alaa Al Khourdajie	IPCC	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
5393	85	5	86	29	All along this paragraph, the author gives a false view of the horizon. In no case, a scenario 100% wind and solar energy can be seriuosly contemplated in 2050, and this si definitively not an objective that a responsible person in charge of its country may rely on. I Fully deaspprove this paragraph which give a false image of the perspective and may lead to desastrus decisios by poltical leaders.	Note that these passages simply summarize the literature and do not offer predictions about the future (or assessments of likelihoods of different futures).	Michel SIMON	Retraité/ Pdt d'association	France
69643	85	9	85	9	CCS offers opportunities for negative emissions under the sole condition that carbon is captured from the atmosphere. CCUS requires another condition, that the use is not a fuel use or another short-live use that would lead to rapid return of the CO2 to the atmosphere. It is important to clearly distinguish CCS and CCU.	We use CCUS here to maintain consistency with other sections of the report.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
12471	85	11	85	16	"the economic value of additional wind and solar capacity typically decreases as their penetration rises due to lower resource value and integration costs, creating economic challenges at higher deployment levels (Wiser et al. 2017; Gowrisankaran et al. 2016; Hirth 2013; Ueckerdt et al. 2013). The integration options above, as well as changes to market design, can mitigate these challenges but likely will not solve them, especially since these technologies can exhibit declining value themselves" The economic value of all normal goods decreases as their penetration rises, by the very definition of a normal good (downward-slopping demande curve). I do not see why this should be pointed out for renewables. Cf. Brown, T., & Reichenberg, L. (2020). Decreasing market value of variable renewables is a result of policy, not variability. arXiv preprint arXiv:2002.05209.	While such intuition may seem obvious to economists, many stakeholders do not appreciate such dynamics. Also, those basic traits do not by themselves indicate anything about effect sizes, hence the importance of research in this area (summarized in the references here).	Philippe Quirion	CNRS	France
78663	85	11	85	14	the statement is in stark contradiction to findings of Bogdanov et al. (https://www.sciencedirect.com/science/article/pii/S0306261920316639) which have analysed in higher technological, temporal and regional detail as the provided references the same, and found that cost continuously decline while approaching 100% renewables, and also during the transition. Please be aware that greenfield studies are less rewardin that pathway scenario studies which also imply the transition over time. The clear conclusion of Bogdanov et al. had been that 100% renewables is LOWER in cost then present day systems, and the decline in cost is continuously achieved, in a cost optimised way. That results shall not be ignored, in particularly taking into accound that several fo the references are not rather old, and Bogdanov et al. has beeen also published in at least equivalent journal level	Note that the sentence and the conclusions of the Bogdanov et al. are not necessarily in conflict. The sentence refers to system outcomes as renewable penetration is increases, but the Bogdanov et al. reference only looks at a 100% renewable system and compares it with a business-as-usual system.	Christian Breyer	LUT University	Finland
82317	85	11	85	14	Considering that technology development is happening very fast in this field (reducing costs, and improving the performance) I found the references used too old, to state the below statement “Although there are no inherent upper bounds on renewable electricity penetration, the economic value of additional wind and solar capacity typically decreases as their penetration rises due to lower resource value and integration costs, creating economic challenges at higher deployment levels (Wiser et al. 2017; Gowrisankaran et al. 2016; Hirth 2013; Ueckerdt et al. 2013)”.	We added newer references here.	Anna Krook-Riekkola	Luleå University of Technology	Sweden
69649	85	14	85	17	Mills, A.D. et alii, 2021, Solar-to-Grid: Trends in System Impacts, Reliability, and Market Value in the United States, Lawrence Berkeley National Laboratory, show that in California, solar's relative market value declined because of a solar-induced shift in the timing of high and low energy prices and a reduction in solar's capacity credit. However, as solar's market valuue declined, its cost declined at a similar pace, thus maintaining solar's overall competitiveness.	We added a newer reference by the same group in this sentence.	Cédric PHILIBERT	Institut Français des Relations Internationales	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
71711	85	20	85	22	This statement strongly depends on cost assumptions for nuclear and CDR compared to 100% RES systems. There is high uncertainty about the future development of these costs. So "high confidence" is not given here, in my view.	We altered this statement to reflect many uncertainties in how net-zero systems might unfold.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
78669	86	1	86	5	IAMs fail in high shares of renewables as mentioned in several research pieces, which has also to do with limited methods in IAMs regardin Power-to-X options, and extremely outdates cost assumptions for renewables, in particular solar PV. Such major findings in literature have to be added, so that a more balanced overview on existing literature is provided, why IAMs fail to present very high shares of renewables. The strong cost bias against solar PV, the most import renewable options is stated in Jaxa-Rozen (https://www.nature.com/articles/s41558-021-00998-8), Creutzig et al. (https://www.nature.com/articles/nenergy2017140), Breyer et al. (https://onlinelibrary.wiley.com/doi/10.1002/pip.2885), and a most recent article by Victoria et al. (2021, Solar photovoltaics is ready to power a sustainable future, Joule, in press)	We included discussions about the relative model detail of different types of modeling frameworks (and how these assumptions may change modeled solutions) in Sections 6.6.1 and 6.6.2.2 (including a couple references the reviewer cites). So we don't repeat these here for brevity.	Christian Breyer	LUT University	Finland
84491	86	1	86	25	The focus on the cost of decarbonisation may be coupled with the co-benefits of the energy transition earlier in the chapter. Existing references on job creation projections include https://doi.org/10.1016/j.techfore.2019.06.008	Cobenefits are addressed in greater detail in other sections, so we don't include discussions or references to those issues in this box for brevity.	Siir KILKIS	The Scientific and Technological Research Council of Turkey	Turkey
28433	86	4	86	4	The SR15 database does not show optimistic cost assumptions, looking at the cost ranges described in Chapter 15 Figure 15.7 of this report more cost declines can be expected	We updated the figures and references to include the AR6 database.	Naud Loomans	Eindhoven University of Technology	Netherlands
17435	86	5	86	6	"Very high renewable and electrification energy systems entail technical and economic challenges as shares approach 100%." This is not a problem if most of the renewable electric capacity is hydro (example - Norway). Without significant hydro share it is a huge problem.	This phrase was detailed from the box.	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
78673	86	6	86	8	the statement shall be expanded as it does not fully express the fundamental conclusion and content of the reference. Expansion to "…, especially at regional but also global levels …" - there is an entire table in the reference with an overview on 100% renewables studies.	The phrase seems to accurately characterize the literature, which (despite a few global studies) primarily focuses on national/regional analysis, as the Hansen, et al. (2019) review suggests. There have since been additional studies of course, but these do not seem to fundamentally alter the conclusion that most studies are regional.	Christian Breyer	LUT University	Finland
78671	86	8	86	9	the statement that bioenergy is downplayed, and in particular 'other renewable fuels' are not considered significantly is not true. In Khalili et al. (https://www.mdpi.com/1996-1073/12/20/3870) in Tab. 27 an overview on the transport sector across scenarios (100% renewables, IAM, fossil scenarios) show that within the 100% renewables community there are two groups one with high bioenergy shares, others with solutions which can avoid high bioenergy shares. In addition, in particualar in the 100% renewables community there are articles with a BROAD variety of renewables fuels, such as green hydrogen, methane, Fischer-Tropsch fuels, methanol and ammonia (see Bogdanov et al. (https://www.sciencedirect.com/science/article/pii/S0306261920316639), and the same is clearly documented by a recent report commissioned by the German Energy Agency (https://www.powerfuels.org/fileadmin/powerfuels.org/Dokumente/Global_Alliance_Powerfuels_Study_Powerfuels_in_a_Renewable_Energy_World.pdf). Therefore, such distorted claims, violating the body of literature shall be corrected, and a broader basis of literature provided, as it's the idea of this AR6.	We added the phase "relative to studies with broader technological choice sets" to convey that this sentence is discussing relative and not absolute magnitudes.	Christian Breyer	LUT University	Finland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
2697	86	9	86	12	Does that even exist? Cost is not a physical observable but depends on regulatory frameworks, subsidies and internalization of externalities. While this sounds very technocratic and scientific, there are a lot of hidden value judgements behind the concept of "costs", making "cost minimization" not technology neutral.	Great point. But space constraints limit our ability to go into greater depth here apart from characterizing at a high level the framing differences between 100% renewables studies and the broader decarbonization literature.	Jan Wohland	ETH Zurich	Switzerland
78675	86	9	86	12	the statement is a false claim! Various options are regularly allowed, but they are not cost competitive, and as a consequence of cost-optimisation they are not part of the solution. Take the recent World Energy Outlook 2020 of the International Energy Agency (see there; see Tables B.2a/b), clearly pointing out that nuclear and fossil CCS is the highest cost source of electricity - that's the fundamental reason why in cost optimisations such high cost options are not part of the solution.	The reviewer's claim conflicts with the literature review provided in Jenkins, et al. (2018b), various model intercomparison studies referenced in the box, and results from the AR6 database, which are summarized in Figure 6.22.	Christian Breyer	LUT University	Finland
78677	86	12	86	17	the opposite is typically true: scenarios finding nuclear as part of the solution regularly have high cost for renewales (often higher as of today), while the real cost of nuclear, but also fossil CCS is played down. Check for instance whether fossil CCS also includes CO2 transport and storage, or only the carbon capture part - very often CO2 transport and storage is simply missing, thus pushing results towards fossil CCS solutions. The real market cost of nuclear is regularly ignored in respective studies. Discussion in Brown et al. https://www.sciencedirect.com/science/article/pii/S1364032118303307 and Child et al. (https://www.sciencedirect.com/science/article/pii/S136403211830176X) is also beneficial for this part.	Note that the claim in the box does not specially call out nuclear or other specific technologies as the reviewer suggestions. The box simply notes the methodological differences between many 100% renewables studies and the broader decarbonization literature.	Christian Breyer	LUT University	Finland
10665	86	18	86	21	This passage essentially duplicates lines 20-22 on page 83	This sentence was removed.	Philippe Waldteufel	CNRS	France
78679	86	18	86	21	this statement does NOT represent the body of literature, as several research pieces show explicitly that cost can even decline when approaching 100% renewables (see Bogdanov et al. https://www.nature.com/articles/s41467-019-08855-1 - and Ram et al. http://energywatchgroup.org/wp-content/uploads/EWG_LUT_100RE_All_Sectors_Global_Report_2019.pdf), while an hourly modeling clearly indicates that the systems are stable. Sub-hourly effects are discussed in Brown et al. (https://www.sciencedirect.com/science/article/pii/S1364032118303307). A more neutral statement is a MUST requirement, and the full body of literature has to be considered, instead of ignroing such research insights.	This sentence was removed.	Christian Breyer	LUT University	Finland
78665	86	20	86	21	this statement is not justified and highly discussed, as several articles find exactly that 100% renewables is the least cost case, also in scenario variations. Therefore another wording and tone is mandatory for this part. This statement is for sure NOT 'high confidence'. See the findings of Ram et al. (http://energywatchgroup.org/wp-content/uploads/EWG_LUT_100RE_All_Sectors_Global_Report_2019.pdf; part of AR6 scenario database) which show cost equal solution with 100% renewables comprising all sectors. Such research results cannot be ignored. See also Hansen et al. (https://www.sciencedirect.com/science/article/pii/S0360544219304967)	This sentence was removed.	Christian Breyer	LUT University	Finland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
78681	86	21	86	29	authors of this text box seem to mix up things, as 100% renewables modellers do not focus on 100% VARIABLE renewables, but on all! This shall be better reflected in wording and in provided references. ALL scientific leaders in the field stress the mix of renewables, as summarised in Hansen et al. (https://www.sciencedirect.com/science/article/pii/S0360544219304967), and stated in Jacobson et al. (https://www.sciencedirect.com/science/article/pii/S2590332219302258), Teske (https://www.springer.com/gp/book/9783030058425) and Bogdanov et al. ((https://www.sciencedirect.com/science/article/pii/S0306261920316639)), also discussed in Brown et al. ((https://www.sciencedirect.com/science/article/pii/S1364032118303307)). The full body of literature shall be better reflected in this part of the AR6, which is not yet achieved.	This sentence was motivated to refer to "renewables" and not "variable renewables" and heavily revised.	Christian Breyer	LUT University	Finland
85789	86	21	86	29	Suggest breaking up this information into several sentences, this sentence is very long and difficult to understand.	The large clause in the middle of this sentence was removed.	Government of Australia	Department of Industry, Science, Energy and Resources	Australia
2875	86	32	86	33	Widespread electrification of end uses requires, among others, a number of measures, e.g. tax reforms to make electricity cheaper in comparison with other energy carriers and innovation in power-to-X, e-mobility and heat pump technologies to achieve cost reductions.	Thank you for your comment. You are right that there would have to be policy and other incentives for achieving some of these transformations. In this chapter, we are focusing on the characteristics of net-zero energy systems, whereas pathways to get there are discussed in Chapter 7.	Leonardo Barreto	Head of center "EU&International"	Austria
63665	86	32	87	48	It should be acknowledged that only a small portion of total secondary energy use is currently met with electricity, and that only 1/3 of current world electricity generation comes from low-carbon sources (renewable and nuclear). What additional low carbon generation capacity would be required to support the widespread electrification of end uses and should all end uses be electrified simply because they can, without consideration of the most appropriate uses of electricity as a limited resource?	Thank you for your comment. You are right that the current level of electrification is significantly smaller than what we describe as the expected level of electrification for a net-zero energy system. The question of what additional generation capacity would be needed to get from today to a net-zero energy system is the focus of Chapter 7. On your question about the most appropriate uses of electricity - Section 6.6.2.4 discusses end uses where low or zero carbon fuels would be more appropriate than electrification.	Government of Canada	Environment and Climate Change Canada	Canada
69651	86	35	85	35	You may want to add to this list Philibert, C., 2019, Direct and indirect electrification of industry and beyond, Oxf Rev Econ Pol, 35, 2: 197-217	Thank you for the reference suggestion. It has been added.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
51407	86	44			as building energy uses (lighting, cooling, and heating) are assumed to be electrified (LEDs and heat pumps)	Thank you for your comment. Section 6.6.2.4 discusses the potential of hydrogen for long-distance freight. Box 6.7 also provides broader applications of hydrogen.	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
71713	86	45	86	47	The role of light industry seems worth pointing out here as well.	Thank you for your comment. The details of light versus heavy industry are addressed in the last paragraph of the section (Page 87 line 38 onwards).	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
64333	87	13	87	20	This section does not fully explain that future district heating is likely to use large-scale heat pumps based on local waste and envirionmental energy sources. Compared with individual air source heat pumps, the benefits of such district heating networks include a) reduced annual electricity consumption, and b) reduced peak demand on the national electricity system as a result of higher winter temperature heat sources and lower heat network transmission temperatures.	Thank you for your comment. The section now has a statement that says "The level of electrification will depend on the tradeoffs between building or household level heat pumps versus more centralized district heating network options."	Peter North	Imperial College (part-time PhD student) /Calorem Ltd	United Kingdom (of Great Britain and Northern Ireland)
82295	87	13	87	20	In the first sentence you state high confidence in “Electrification of most buildings services, with the possible exception of space heating in extreme climates, is expected in net-zero energy systems”. I haven’t had the time to read the Building chapter, but do they really conclude that “Electrification of most buildings services” is needed in net-zero energy systems? Hence that we in Denmark, Finland and Sweden should replace district heating with electric heating? If yes, please point at studies showing this. And how you derive to this conclusions despite significant amount of studies showing the benefits from district heating in decarbonization: • In Sweden “In multi-dwelling buildings and nonresidential facilities district heating is by far the most common energy carrier.” (The Swedish Energy Agency (2020) Energy in Sweden 2020 An overview. Downloaded from: https://energimyndigheten.a-w2m.se/Home.mvc?ResourceId=174155) • Taking an energy system approach on the heating sector: To replace district heating with heat-pumps would increase the peak demand during winter time (especially during cold hours when the wind might now blow as much), hence increase the demand for peak hour power capacity, hence make it more difficult to reach net-zero emissions. • District heating has been an important part of the carbonization of for example Sweden (we write about it chapter 2.1 in the following paper: Millot A., Krook-Riekkola A., Maïzi N. (2020) Guiding the future energy transition to net-zero emissions: Lessons from exploring the differences between France and Sweden. Energy Policy, Volume 139. https://doi.org/10.1016/j.enpol.2020.111358 • Sven Werner have published a paper with the title “District heating and cooling in Sweden, which could be useful for you: https://doi.org/10.1016/j.energy.2017.03.052 o OVERALL BENEFITS: “The main conclusions are high utilisation of district heating in Swedish buildings, commitment to the third generation of district heating technology,	Thank you for your comment. The section now has a statement that says "The level of electrification will depend on the tradeoffs between building or household level heat pumps versus more centralized district heating network options."	Anna Krook-Riekkola	Luleå University of Technology	Sweden
84493	87	17	87	20	The phrase "heat pumps versus district heating" does not take into account the possibility of large-scale heat pumps in urban energy infrastructure. Multiple references exist on the role of large-scale heat pumps in decarbonization and its flexible operation to support fourth generation solutions including but not limited to https://doi.org/10.1016/j.energy.2019.05.122 and https://doi.org/10.1016/j.enconman.2020.113379.	Thank you for your comment. The section now has a statement that says "The level of electrification will depend on the tradeoffs between building or household level heat pumps versus more centralized district heating network options."	Siir KILKIS	The Scientific and Technological Research Council of Turkey	Turkey
21071	87	34	87	34	There is however shore electric power supply in ports for 'large ships'. Ref.: “SHORE TO SHIP” SYSTEM – AN ALTERNATIVE ELECTRIC POWER SUPPLY IN PORT Tadeusz Borkowski, Dariusz Tarnapowicz January 2015Journal of KONES 19(3):49-58 DOI: 10.5604/12314005.1137943	Thank you for your comment. Although potential options exist for electrification, this statement is highlighting how they might be more limited when it comes to large ships, resulting in a relatively low level of electrification when compared to light duty vehicles or other easier to electrify transport options. Due to space limitations we unfortunately cannot go into the details of each of these options.	Government of France	Ministère de la Transition écologique et solidaire	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
28435	87	34	87	37	"Long-haul trucks, large ships and aircrafts are expected to be harder to switch to electrification, so the expected share of electricity serving these end uses directly will be relatively low absent technological breakthroughs (Fulton et al. 2015; Mathiesen et al. 2015)." The potential of long-haul trucks is larger than often imagined. The distinction between long-haul and heavy trucks is often unclear. The result of this is that there is relatively little attention to electric trucks in this segment. To make a clear distinction in terms of any electric vehicle or transport mode. Heavy or light is not a relevant destinction, in fact the heavier a truck is the less the relative added weight of a battery making it less problamatic (Nykvist & Olsson, 2021). The only issue is mobility modes with long continous operating hours. In terms of long haul trucks this would mean that only the fraction driving over 500km a day without relatively long intermediate stops are not able to be electrified. And even these ranges will increase with further battery development and ultra-fast charger capacity. Especially in a European context this is only a small minority of all trips currently stated as long-haul and heavy duty	Thank you for your comment. We have reframed the high level takeaway to address this point. It now reads: "Long-haul trucks, large ships and aircrafts are expected to be harder to switch to electrification, so the expected share of electricity serving these end-uses directly will be relatively low absent technological breakthroughs (Fulton et al. 2015; Mathiesen et al. 2015); however, continued improvements in battery technology can make electrification of long-haul trucks particularly promising (Nykvist & Olsson 2021; also see Chapter 10)."	Naud Loomans	Eindhoven University of Technology	Netherlands
69653	87	34	87	37	The cases of long-distance ships and aircrafts must be distinguished from that of long-haul trucks, as the electrification of the latter is making rapid progress. The distances run by ocean-going ships and medium and long-haul aviation are quite different from the distances that "long-haul" trucks would need to run between refills.	Thank you for your comment. We have reframed the high level takeaway to address this point. It now reads: "Long-haul trucks, large ships and aircrafts are expected to be harder to switch to electrification, so the expected share of electricity serving these end-uses directly will be relatively low absent technological breakthroughs (Fulton et al. 2015; Mathiesen et al. 2015); however, continued improvements in battery technology can make electrification of long-haul trucks particularly promising (Nykvist & Olsson 2021; also see Chapter 10)."	Cédric PHILIBERT	Institut Français des Relations Internationales	France
85499	87	34	87	37	The text states: "Long-haul trucks, large ships and aircrafts are expected to be harder to switch to electrification, so the expected share of electricity serving these end uses directly will be relatively low absent technological breakthroughs (Fulton et al. 2015; Mathiesen et al. 2015)." Unfortunately, most people equate long-haul with heavy class-8 trucks (that are responsible for 30% of all transport emissions) so they will read this as "most heavy trucks cannot be electrified". Also, we have to cure people of the persistent idea (pervasive in chapter 10) that electrification becomes harder as the size of a vehicle increases. A new publication by Nykvist (that you might know of his battery article in Nature) and Ollsen in the high-ranking journal Joule makes this very clear. The article will appear in the April issue and is titled: "The feasibility of heavy battery electric trucks". It shows that as vehicles become heavier, the battery to payload ratio decreases. This is also true for ships and planes. Range per se is also not the best metric. Instead it is the ratio between maximum range and average range that predicts if a business case is good for trucks. For example: trucks that drive no more than 800km per day (over 80% of trucks) but travel more than 500km per day on average (again over 80% of trucks) have a really good business case with current batteries already. A formulation to avoid giving oxygen to the misconception that larger size makes electrification harder could be something along the lines of: "Although electrification actually becomes easier as trucks become heavier (Nykvist and Ollsen 2021), long range requirements are hard to provide with batteries, especially for ocean vessels that often travel very large distances without interruption, and most explicitly for airplanes where the weight of fuel is also critical."	Thank you for your comment. We have reframed the high level takeaway to address this point. It now reads: "Long-haul trucks, large ships and aircrafts are expected to be harder to switch to electrification, so the expected share of electricity serving these end-uses directly will be relatively low absent technological breakthroughs (Fulton et al. 2015; Mathiesen et al. 2015); however, continued improvements in battery technology can make electrification of long-haul trucks particularly promising (Nykvist & Olsson 2021; also see Chapter 10)."	Auke Hoekstra	Eindhoven University of Technology	Netherlands

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
51409	87	36	87	37	directly will be relatively low absent technological breakthroughs (Fulton et al. 2015; Mathiesen et al. 2015). Though	Thank you for your comment. Section 6.6.2.4 discusses the potential of hydrogen for long-distance freight. Box 6.7 also provides broader applications of hydrogen.	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
51411	87	36	87	37	hydrogen fuel cells are becoming an option for long-distance freight.	Thank you for your comment. Section 6.6.2.4 discusses the potential of hydrogen for long-distance freight. Box 6.7 also provides broader applications of hydrogen.	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
51413	87	36	87	37	{ see https://thedriven.io/2021/03/02/toyota-says-hydrogen-fuel-cell-module-can-power-trucks-buses-trains-and-ships/	Thank you for your comment. Section 6.6.2.4 discusses the potential of hydrogen for long-distance freight. Box 6.7 also provides broader applications of hydrogen.	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
55815	87	38	87	40	Recommend rewording to ensure focus of sentence is on decarbonization rather than limitations of electrification. For example, "A non-trivial number of industry applications may be decarbonized more effectively using chemical feedstock and renewable gases, such as hydrogen, rather than via electrification."	Thank you for your comment. The alternative ways for decarbonization that can substitute for electrification are discussed in more detail in Section 6.6.2.4 whereas the focus of this section is on highlighting where electrification is promising versus less so.	Government of United States of America	U.S. Department of State	United States of America
78683	87	38	88	3	please add a recent an structurally new finding in literature: it is possible to directly and indirectly switch the entire industry sector to zero GHG emissions for all energy and fuel use using only electricity, as shown in hourly resolution for an entire energy-industry transition detailing cement, steel, chemicals and aluminum - see Bogdanov et al. (https://www.sciencedirect.com/science/article/pii/S0306261920316639)	Thank you for your comment. We agree that some studies such as the one you point to have indicated that the entire energy industry could potentially be electrified, but we keep our focus to the notion that we do not expect that based on the weight of the evidence.	Christian Breyer	LUT University	Finland
84359	87	42	87	42	Please add: ICT extra-energy consumption for smart control, tension on functional/structural materials	Thank you for your comment. Unfortunately space limitations prevent us from going into a greater level of detail here.	Vincent MAZAURIC	Schneider Electric	France
2877	87	45	87	47	Alternatives to electricity are required for very high temperature end uses in industry. Here, hydrogen and other fuels can play a role	Thank you for your comment. Section 6.6.2.4 discusses the potential of hydrogen and other fuels in harder to electrify industrial sectors.	Leonardo Barreto	Head of center "EU&International"	Austria
69655	87	47	88	1	Madeddu et al. 2020 gives numbers quite different from the 60% attributed here to this reference: "Seventy-eight per cent of the energy demand is electrifiable with technologies that are already established, while 99% electrification can be achieved with the addition of technologies currently under development."	Thank you for your comment. The numbers underlie their Figure 2 (see lower panel), and this statement in section 4.3: "When including technologies with low technological maturity and high uncertainty in chemicals, cement, and steel, the maximum electrification potential increases to 60% of the UE demand (4.7 EJ) in St3 (red bars in figure 2). The remaining 40% cannot be supplied directly with electricity because fossil fuels are used for metallurgical purposes in non-ferrous metals and EAFs, and as chemical feedstocks."	Cédric PHILIBERT	Institut Français des Relations Internationales	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
69657	88	1	88	3	I couldn't find such or similar statement in Madeddu et al. 2020.	Thank you for your comment. The two comments that mention this are "Despite its decarbonisation potential, the extent to which direct electrification will be deployed in industry remains uncertain and depends on the relative cost of electric technologies compared to other low-carbon options." and "Despite the many advantages, the extent to which direct electrification will be deployed in industry remains uncertain and depends on the relative cost of electric technologies compared to other low-carbon options".	Cédric PHILIBERT	Institut Français des Relations Internationales	France
79783	88	4	89	9	The Section 6.6.2.4 discuss the use of Alternative fuels in Hard-to-Decarbonise Sectors. In this section the authors do not mentioned adequately the waste-derived fuels which is now very common in heavy industry. Industrial sectors like the cement industry are using a variety of waste-derived fuels globally trying to reduce the use of fossil fuels and increase the dual approach on high calorific fuels coming from different industrial wastes. This approach is presenting multiple benefits, as the energy-intensity industry is used to address also the issue of waste management by utilizing difficult wastes (waste-oils, waste plastics/hard plastics) which usually cannot enter in the economy as other products or treated environmental-friendlier with other means. For this issue there are multipole publications coming mainly from Earth Engineering Center of Columbia University N.Y. (e.g. https://doi.org/10.1108/MEQ-01-2015-0012) and from India e.g. https://doi.org/10.1080/15567036.2018.1555630, etc.	Thank you for your comment. The revised text mentions heat for industry among the services that might be supplied by wastes and references Chatziaras et al. as well as more recent relevant papers by Thiel and Stark (2020) and Fennell et al. (2021).	Constantinos Psomopoulos	University of West Attica, Department of Electrical and Electronics Engineering	Greece
78685	88	5	88	14	this has been shown in high detail and based on hourly resolution in fossil free energy-industry systems for the sustainable and net-zero emission fuels hydrogen, methane, Fischer-Tropsch, methanol and ammonia in Bogdanov et al. (https://www.sciencedirect.com/science/article/pii/S0306261920316639) and a report commissioned by the German Energy Agency (https://www.powerfuels.org/fileadmin/powerfuels.org/Dokumente/Global_Alliance_Powerfuels_Study_Powerfuels_in_a_Renewable_Energy_World.pdf)	Thank you for your comment, but not clear if you are suggesting a revision.	Christian Breyer	LUT University	Finland
71715	88	8	88	8	Precisely speaking, most liquid carbon-based fuels such as methanol are not hydrocarbons, as hydrocarbons have to consist of hydrogen and carbon only. So better say liquid carbon-based fuels.	Thank you for the comment. "Hydrocarbon" has be changed to "carbon-based fuels" as suggested at first use. However, much of the foundational literature refers to these fuels as hydrocarbons (e.g., Zeman and Keith, 2008)	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
55817	88	10	88	10	Recommend also providing use of renewable hydrogen as a feedstock in existing chemical manufacturing process (e.g., for ammonia) as an example.	Thank you for the comment. Hydrogen for ammonia is mentioned in the paragraph beginning "Costs are the main barrier...", but the section is about fuels and not chemical feedstocks. Feedstocks are mentioned in Box 6.7	Government of United States of America	U.S. Department of State	United States of America
66717	88	10	88	19	I find repetitive the following two sentences: 'The resulting energy-dense fuels can serve applications that are difficult to electrify, such as long-distance freight, long-haul aviation and high-temperature industrial heating (Davis et al. 2018; NAS 2016).' and 'CO2 emissions from some energy services are expected to be particularly difficult to cost-effectively avoid, among them aviation; long-distance freight by ships, trains, and trucks; process emissions from cement and steel production; high-temperature heat (e.g., >1000°C); and electricity reliability in systems with high penetration of variable renewable energy sources (Davis et al. 2018; Luderer et al. 2018; (Chiaramonti 2019; Sepulveda et al. 2018; Bataille 2020; Rissman et al., 2020)	Thank you for the comment. The revised text removes the repetition.	Chiodi Alessandro	E4SMA	Italy

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
69659	88	12	88	12	Electric arc furnaces, plasma torches, etc. achieve temperature levels >3000°C, higher than the combustion level of hydrocarbons or hydrogen. High-temperature industrial heat is not "difficult to electrify".	Thank you for the comment. High-temperature heat is difficult to electrify *cost-effectively* as detailed in the referenced literature (Thiel and Stark; Madeddu).	Cédric PHILIBERT	Institut Français des Relations Internationales	France
69661	88	12	88	14	It is not clear what this sentence exactly means. There are no proven ways of managing the carbon "related" to the combustion of fossil fuels in long-distance freight or long-hault aviation.	Thank you for the comment. Various options for air capture have been demonstrated and may be cost-effective. The revised text clarifies and adds a recent reference.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
69663	88	15	88	19	Solutions have been identified for most of the cases mentioned here, ranging from direct electrification and battery electrification for trains and trucks, and high-temperature heat; production of green ammonia for combustion in modified marine internal combustion engines; production nof low-carbon e-kerosene for aviation; green hydrogen based direct reduction for steel production; electrification, changes in clinker composition and CCS for cement production.	Thank you for the comment. The text emphasizes cost-effectiveness. As revised, it states explicitly that solutions do exist but remain expensive, early-stage, and/or subject to sustainability concerns.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
78687	88	15	88	24	indeed, literature is limited, however, it has been shown by Ram et al. (http://energywatchgroup.org/wp-content/uploads/EWG_LUT_100RE_All_Sectors_Global_Report_2019.pdf ; scenario is part of AR6 scenario database), that a cost-neutral transition until 2050 is possible for the entire energy system, including the hard to abate segments (high-temperature industry, long-distrance marine/ aviation, etc.). Such information shall be added.	Thank you for the comment. The pointed to study does not support a general conclusion of cost-effectiveness. As revised, the text states that solutions do exist but remain expensive, early-stage, and/or subject to sustainability concerns.	Christian Breyer	LUT University	Finland
55819	88	16	88	16	States that it will be difficult to reduce CO2 emissions from trains, but an earlier section said it would be easy to electrify rail.	Thank you for the comment. Trains have been removed from the list.	Government of United States of America	U.S. Department of State	United States of America
10965	88	19	88	19	delete "(" in 2018: (Chiaramonti 2019;"	Thank you, corrected.	Dong-Woon NOH	Korea Energy Economics Institute	Republic of Korea
16389	88	19	88	19	delete "(" in 2018: (Chiaramonti 2019;"	Thank you, corrected.	Government of Republic of Korea	Korea Meteorological Administration (KMA)	Republic of Korea
71717	88	19	88	21	While I agree that it is not clear what the most promising options are, I do not agree with the statement that the literature is limited. There is a broad literature addressing CCS, hydrogen and synthetic and alternatvie fuels. Some but less sources are available on low-carbon clinkers, electrification of high-temperature processes and trolley trucks.	Thank you for the comment. The revised text acknowledges that the literature is growing and adds a number of new references in the described areas.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
69665	88	22	88	24	This is one view. A very different view, rooted in facts, is proposed by, e.g., Energy Transition Commission, 2018, Mission Possible.	Thank you for the comment. The text is supported by a large and diverse body of literature. It is not clear whether you are suggesting a revision.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
78689	88	25	88	35	several studies have been shown that a very low share of biofuels in transportation does not block a zero GHG emission transport sector, even on 100% renewables basis as summarised by Khalili et al. (https://www.mdpi.com/1996-1073/12/20/3870) - see Tab. 27	Thank you. The comment does not seem to conflict with the text as written.	Christian Breyer	LUT University	Finland
2883	88	29	88	34	Liquid biofuels will have to comply with stringent sustainability and GHG savings criteria similar to those outlined by the EU renewable energy directive 2018/2001 incluidng indirect land use change and systems for verification of compliance with these sustainability criteria throughout the entire chan of custody must be put in place.	Thank you for the comment and agreed. The text notes these sorts of sustainability concerns more generally.	Leonardo Barreto	Head of center "EU&International"	Austria
55821	88	33	88	33	Is CDR an objective? It does not appear to fit with the other listed objectives in this sentence.	Thank you for the comment. Land-based carbon removal via a/reforrestation is a key strategy of carbon management in many energy-emissions scenarios.	Government of United States of America	U.S. Department of State	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
7889	88	36	89	4	In previous pages with mention of the cost of hydrogen from different pathways - Newborough and Cooley is mentioned - so it might be worth looking at that for this section too	Thank you for the comment and suggestion. A reference to Newborough and Cooley has been added.	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
55823	88	36	88	41	Recommend using more recent reference, and showing a range for electrolysis costs of $5-$7/kg (https://www.hydrogen.energy.gov/pdfs/20004-cost-electrolytic-hydrogen-production.pdf)	Thank you for the comment. The section has been revised to use a range and the suggested reference.	Government of United States of America	U.S. Department of State	United States of America
61829	88	36	89	4	This section should include remark from more recent literature on hydrogen production. For example, (Kayfeci et at. 2019, https://doi.org/10.1016/B978-0-12-814853-2.00003-5) states that hydrogen from biomass and nuclear energy would be significantly less than the mentioned $5.5/kg. The recent report (LucidCatalyst, 2021, https://www.lucidcatalyst.com/hydrogen-report) has hydrogen from existing nuclear PWR technology at less than $2/kg and from GEN IV technology at $1/kg or less.	Thank you for the comment. The section has been revised to use a range of levelized hydrogen costs as compiled and recently reported by the U.S. Department of Energy and other studies.	Rauli Partanen	Think Atom	Finland
65865	88	36	89	4	Could you please comment on the more recent literature on hydrogen production? For example, (Kayfeci et at. 2019, https://doi.org/10.1016/B978-0-12-814853-2.00003-5) states that hydrogen from biomass and nuclear energy would be significantly less than the mentioned $5.5/kg. The recent report (LucidCatalyst, 2021, https://www.lucidcatalyst.com/hydrogen-report) lists hydrogen from existing nuclear PWR technology at less than $2/kg and from GENIV technology at $1/kg or less.	Thank you for the comment. The section has been revised to use a range of levelized hydrogen costs as compiled and recently reported by the U.S. Department of Energy and other studies.	Eero Hirvijoki	Aalto University	Finland
71719	88	36	88	36	Precisely speaking, most liquid carbon-based fuels such as methanol are not hydrocarbons, as hydrocarbons have to consist of hydrogen and carbon only. So better say liquid carbon-based fuels.	Thank you for the comment. "Hydrocarbon" has be changed to "carbon-based fuels" as suggested at first use. However, much of the foundational literature refers to these fuels as hydrocarbons (e.g., Zeman and Keith, 2008)	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
78691	88	36	89	4	much of the cost numbers is outdated and does not discribe well the cost projections and trajectories discussed in literature. See the recent hydrogen report of IRENA (https://www.irena.org/publications/2020/Dec/Green-hydrogen-cost-reduction), and the hydrogen cost projections of Fasihi and Breyer (https://doi.org/10.1016/j.jclepro.2019.118466)	Thank you for the comment. The section has been revised to use a range of levelized hydrogen costs as compiled and recently reported by the U.S. Department of Energy and other studies.	Christian Breyer	LUT University	Finland
2885	88	37	88	39	Although the figures cited appear to be in the current range of costs, the reference seems outdated	Thank you for the comment. The section has been revised to use a range of levelized hydrogen costs as compiled and recently reported by the U.S. Department of Energy and other studies.	Leonardo Barreto	Head of center "EU&International"	Austria
75863	88	38	88	39	This needs to be consistent with Table 6.7 (and perhaps make cross reference)	Noted	Herib Blanco	International Renewable Energy Agency (IRENA)	Germany
66719	88	39	88	39	Fullstop missing	Thank you.	Chiodi Alessandro	E4SMA	Italy
71721	88	39	88	45	The reference Graves et al. 2011 is rather old. Consider to add the most recent literature, e.g. Lux and Pfluger (2020) and references therein, Lux and Pfluger (2020): A supply curve of electricity-based hydrogen in a decarbonized European energy system in 2050. Applied Energy, 269, 115011	Thank you for the comment. The suggested reference does not report hydrogen production costs per kg but rather discusses the scale of production available at different electricity systems costs and configurations. The revised text nonethless updates the references in this section.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
69667	88	41	88	42	A reference dating back to 2011 cannot provide a reference for costs "today". The cost of PV has been divided by ten since then! In many places, a combination of solar and wind, or wind and hydro, can sustain high electrolysers utilisation rates with electricity at ~30 USD/MWh. PV only run electrolysers can have utilisation rates of 40% with little curtailment, and benefit from even cheaper electricity in some places, now around 15 USD/MWh. Large-scale electrolysers (>100 MW) are now proposed at prices <1000 USD/kW in industrialised economies. This brings the costs of H2 close to 2 USD/kg (see Philibert C., 2017, Renewable Energy for Industry, IEA Insights Paper; IEA, 2019, The Future of Hydrogen; Armijo, J. and Philibert C., 2020, Flexible production of hydrogen and ammonia from variable solar and wind energy: Case study of Chile and Argentina, Int. J. Hydrog Energy 45, 3, 1541-1558., Costs of alkaline electrolysers in China are said to be ~200 USD/kW, and there is no doubt that learning and economies of scale will rapidly reduce the costs of electrolysers as the market expands - it has only begun to expand in 2020 to 200 MW globally, 30% more than in 2019 - but GW are to come in the next few years. Costs of green hydrogen may reach USD 1.5 by 2030 in some places such as the Iberian Peninsula.	Thank you for the comment. The section has been revised to use a range of levelized hydrogen costs as compiled and recently reported by the U.S. Department of Energy and other studies.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
75867	88	41	88	42	One recent IRENA report looking at costs from renewable hydrogen might be a useful reference [27] [27] https://www.irena.org/publications/2020/Dec/Green-hydrogen-cost-reduction	Thank you for the comment. The section has been revised to use a range of levelized hydrogen costs as compiled and recently reported by the U.S. Department of Energy and other studies. Potential economies of scale are also mentioned in the revised text, with reference to the IRENA report.	Herib Blanco	International Renewable Energy Agency (IRENA)	Germany
2887	88	42	88	42	The reference seems to be outdated	Thank you for the comment. The section has been revised to use a range of levelized hydrogen costs as compiled and recently reported by the U.S. Department of Energy and other studies.	Leonardo Barreto	Head of center "EU&International"	Austria
51415	88	42			But 2020 prices of renewable electricity can be as low as Euro 37/MWh in which case the cost of H2 is Euro 2.5/kg	Thank you for the comment. The section has been revised to use a range of levelized hydrogen costs as compiled and recently reported by the U.S. Department of Energy and other studies.	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
51417	88	42			see https://www.euractiv.com/section/energy/opinion/what-is-the-real-cost-of-green-hydrogen/	Thank you for the comment. The section has been revised to use a range of levelized hydrogen costs as compiled and recently reported by the U.S. Department of Energy and other studies.	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
55825	88	45	88	48	The sentence is combining electrolysis and fuel cells in one sentence. It would be cleaner to separate and only describe one to avoid confusion. Since the prior text was around electrolysis, recommend reworking this sentence to: "R&D efforts are targeting reductions in cost and advancements in performance of novel methods of hydrogen production, such as high-temperature electrolysis, photoelectrochemical water splitting, and thermochemical water splitting."	Thank you for the comment. The sentence has been revised to remove mention of fuel cells.	Government of United States of America	U.S. Department of State	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
75865	88	45	88	48	One recent IRENA report looking into the areas for further research might be a useful reference [27] [27] https://www.irena.org/publications/2020/Dec/Green-hydrogen-cost-reduction	Thank you for the comment. Potential economies of scale are also mentioned in the revised text, with reference to the IRENA report.	Herib Blanco	International Renewable Energy Agency (IRENA)	Germany
71723	88	46	88	46	I suppose you mean to refer to high-temperataure electrolysis here, not "fuel cells"?	Thank you for the comment. The sentence has been revised to remove mention of fuel cells.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
55827	89	4	89	4	Within this box, recommend including a reference to recent documents, such as the DOE Hydrogen Program Plan: https://www.hydrogen.energy.gov/pdfs/hydrogen-program-plan-2020.pdf	Noted	Government of United States of America	U.S. Department of State	United States of America
71725	89	5	89	6	Conversion losses when converting hydrogen to carbon-based fuels and corresponding cost increases should also be mentioned here.	Thank you for the comment. Such inefficiences are part of the reported costs.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
78483	89	10	89	11	Figure 6.23: The pumped hydro storage should not have a river, because potential sites for off-river pumped hydro are far larger than when there is a river nearby, see my comment above (page 54).	Thank you for the comment. The figure is highly schematic. Some pumped storage locations are located riverside.	Pietro Altermatt	Trinasolar, Changzhou, China	Germany
28963	89	12	89	12	I propose to change the figure caption to: An example of methods to address hard-to-electrify sectors in energy systems (Source: Davis et al. 2018)	Thank you for the comment. The caption has been revised.	Fabian Heymann	INESC TEC	Switzerland
29431	89	15	90	41	Consider adding data for protonic membrane reformer (PMR) in table 6.6. (Malerød-Fjeld, Clark, & Yuste-Tirados, 2017)	Not relevant to this section	Government of Norway	Norwegian Environment Agency	Norway
61831	89	15	90	44	Box 6.7, please just use "low-carbon electricity". Adding the unnecessary "renewable" makes it less accurate, less technology neutral, more complex and less consistent with climate mitigation, as not all renewable energy is sustainable or has a sufficiently low climate forcing effect. .	Fixed	Rauli Partanen	Think Atom	Finland
65867	89	15	90	44	Box 6.7 requires a thorough revision. The cited reference (Graves et al., 2011, https://doi.org/10.1016/j.rser.2010.07.014) reports that "[t]he dominant costs of the process are the electricity cost and the capital cost of the electrolyzer, and this capital cost is significantly increased when operating intermittently (on renewable power sources such as solar and wind)." The cited reference (Kayfeci et at. 2019, https://doi.org/10.1016/B978-0-12-814853-2.00003-5) lists hydrogen from biomass and nuclear at most half the cost of hydrogen from solar or wind. The recent report (LucidCatalyst, 2021, https://www.lucidcatalyst.com/hydrogen-report) lists hydrogen from existing nuclear PWR technology at less than $2/kg and from GENIV technology at $1/kg or less. COMMENT CONTINUES	This section is improved siginifcantly to presented different production technologies:"Hydrogen produced from natural gas has been an essential feedstock to the petrochemical sector for decades. In order for hydrogen to support decarbonization, it will need to be produced from low/zero-carbon energy sources or, if not, offset by carbon sequestration. 'Blue' hydrogen would be produced from natural gas through the process of autothermal reforming (ATR) or steam methane reforming (SMR), gasification of biomass (i.e., potential to achieve negative carbon emissions (IRENA 2019d)), combined with carbon capture and storage (CCS) technology, and other processes such as pyrolysis of methane (Sanchez-Bastardo et al., 2020). 'Green' hydrogen can be produced from low/zero carbon energy sources such as renewables, biogas, and nuclear using high temperature reactors (Jaszczur et al. 2016) in electrolysis process (Schmidt et al. 2017a) and thermochemical water splitting (EERE 2020)."	Eero Hirvijoki	Aalto University	Finland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
65869	89	15	90	44	COMMENT CONTINUES: None of this information is now delivered and, instead, it is mentioned that hydrogen "would be produced by the electrolysis of water via low-temperature electrolysis (LTE) or high-temperature electrolysis (HTE) processes, using renewable or other low-carbon electricity sources." What are these other low-carbon electricity sources? Why are renewables singled out and mentioned explicitly while research clearly points the economic advantages of producing hydrogen with nuclear? Revise and provide a corrected view of hydrogen production with different technologies.	This section is improved siginifcantly to presented different production technologies:"Hydrogen produced from natural gas has been an essential feedstock to the petrochemical sector for decades. In order for hydrogen to support decarbonization, it will need to be produced from low/zero-carbon energy sources or, if not, offset by carbon sequestration. 'Blue' hydrogen would be produced from natural gas through the process of autothermal reforming (ATR) or steam methane reforming (SMR), gasification of biomass (i.e., potential to achieve negative carbon emissions (IRENA 2019d)), combined with carbon capture and storage (CCS) technology, and other processes such as pyrolysis of methane (Sanchez-Bastardo et al., 2020). 'Green' hydrogen can be produced from low/zero carbon energy sources such as renewables, biogas, and nuclear using high temperature reactors (Jaszczur et al. 2016) in electrolysis process (Schmidt et al. 2017a) and thermochemical water splitting (EERE 2020)."	Eero Hirvijoki	Aalto University	Finland
75723	89	15			Box 6.7: it should be mentionned that rapid and substantial breakthrough are to be expected in the coming years given the amount of investment and number of research projects conducted in the area of hydrogen economy from production to storage (review by Abe J.O., Popoola A.P.I., Ajenifuja E., and Popoola O.M. (2019) Hydrogen energy, economy and storage: Review and recommendation. International Journal of Hydrogen Energy 44, 15072-15086, https://doi.org/10.1016/j.ijhydene.2019.04.068).	The following is updated/added:"Recent developments and improvements in hydrogen production technologies in terms of efficiency and capital costs (e.g., PEM and SOEC electrolyzers) (Mayyas et al. 2019) are increasing the viability of hydrogen in low carbon energy systems (Schmidt et al. 2017b). For example, the trajectory needed to limit global warming at 1.5°C could make electrolyzers about 40% cheaper by 2030 (IRENA, 2020). "	Sylvain Pichat	University of Lyon, Ecole normale supérieure de Lyon, Laboratoire de Géologie (LGL-TPE)	Germany
78695	89	15	90	41	a most important aspect of the 'hydrogen economy' is missing. This is the fact that MOST hydrogen produces will be not used as a final energy fuel, but furhter converted to more suited forms of energy, therefore the expression 'Hydrogen-to-X' maybe well suited to be added in an additional paragraph. See the findings of a recent report commissioned by the German Energy Agency (https://www.powerfuels.org/fileadmin/powerfuels.org/Dokumente/Global_Alliance_Powerfuels_Study_Powerfuels_in_a_Renewable_Energy_World.pdf), or the detailed modelling of Bogdanov et al. (https://www.sciencedirect.com/science/article/pii/S0306261920316639), or the fundamental results of Ram et al. (http://energywatchgroup.org/wp-content/uploads/EWG_LUT_100RE_All_Sectors_Global_Report_2019.pdf ; also in the AR6 scenario databasis), showing very high hydorgen production but having most further converted to methan, Fischer-Tropsch fuels, methane and ammonia, or for materials refining such as steel. This most important aspect is missing.	The following is added:"Another important aspect of hydrogen economy is that significant share of produced hydrogen could be converted to appropriate forms of energy vectors (Global Alliance, 2020) and according to 2020 German national hydrogen strategy, Power-to-X (PtX) technologies will be applied (Mitsui & Co., 2020). "	Christian Breyer	LUT University	Finland
71727	89	16	90	7	In my view, the term "hydorgen economy" encompasses a central role of hydrogen in the energy system, allowing to store electricity and to produce all kind of fuels. The box also misses key applications of hydrogen currently seen as promising, such as hydrogen-based steel production.	The section is signifacntly improved	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
69669	89	19	89	21	Given the large energy penalty in the use of hydrogen, its role is more likely to be limited to that of "range-extenders" in light and heavy duty vehicles primarily running on batteries.	The following sentence is added/updated: "In particular, hydrogen could play a major role in areas that are difficult to decarbonize (e.g., aviation, heavy duty transport, waste, agriculture etc.) (BloombergNEF, 2020). "	Cédric PHILIBERT	Institut Français des Relations Internationales	France
71729	89		89		Box 6.7: Please refer to the figure in the text.	Fixed	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
69671	90	1	90	3	Hydrogen can indeed be used to help ensure electricity security in systems dominated by solar and wind and be combusted in gas peakers, but the wording "replace natural gas-based electricity generation" is ambiguous as it may let the reader think hydrogen will be used with "mid-merit" capacity factors, i.e. 2000 to 4000 full load hours, which is much less likely given the energy penalty of PtX then XtP. The role for trading is more convincing as the resource difference between different regions may significantly alleviate the energy penalty.	The following is updated:"Furthermore, it could provide long-term storage to provide resilience in systems dominated by solar and wind (IRENA 2019d), while enabling the trading of electricity between different regions to overcome seasonal production differences. Hydrogen could also be used for heating, transport of energy over long distances, and industrial processes (e.g., as feedstock for the chemical industry or direct reduction of iron ore (Vogl et al. 2018)). Countries may be able to export hydrogen or hydrogen-based fuels to better support global mitigation efforts"	Cédric PHILIBERT	Institut Français des Relations Internationales	France
69673	90	4	90	6	Using hydrogen for (space) heating is rather unlikely, as with an overall efficiency of 50 to 60% in the use of primary electricity, it requires two to three times more electricity than heat pumps with seasonal performance factor of 3.	Hydrogen can replace natural gas in gas boilers, so it can play a role in this context.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
55829	90	8	90	8	Recommend rewording to: "Hydrogen produced from natural gas has been an essential feedstock to the petrochemical sector for decades. Broader use of renewable hydrogen and fuel cell technologies in new applications has been limited by their cost."	This section is improved siginifcantly to presented different production technologies:"Hydrogen produced from natural gas has been an essential feedstock to the petrochemical sector for decades. In order for hydrogen to support decarbonization, it will need to be produced from low/zero-carbon energy sources or, if not, offset by carbon sequestration. 'Blue' hydrogen would be produced from natural gas through the process of autothermal reforming (ATR) or steam methane reforming (SMR), gasification of biomass (i.e., potential to achieve negative carbon emissions (IRENA 2019d)), combined with carbon capture and storage (CCS) technology, and other processes such as pyrolysis of methane (Sanchez-Bastardo et al., 2020). 'Green' hydrogen can be produced from low/zero carbon energy sources such as renewables, biogas, and nuclear using high temperature reactors (Jaszczur et al. 2016) in electrolysis process (Schmidt et al. 2017a) and thermochemical water splitting (EERE 2020)."	Government of United States of America	U.S. Department of State	United States of America
55831	90	8	90	14	In Box 6.7, authors should describe what industries or use cases would drive down hydrogen and transportation costs as it becomes a new energy carrier. For example, although utility-scale batteries have achieved significant cost reductions in the electricity sector, the electric vehicle manufacturers have driven down the cost of battery production in the past 5-10 years	The following is added to the text:"). In particular, hydrogen could play a major role in areas that are difficult to decarbonize (e.g., aviation, heavy duty transport, waste, agriculture etc.) (BloombergNEF, 2020). "	Government of United States of America	U.S. Department of State	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
69675	90	8	90	8	What does this mean? 70 Mt H2 are produced pure and "on purpose" in 2018 (IEA 2019, The Future of Hydrogen), and this production in most of the Xxe Century took place in hydropower-run electrolysers. This would not have happened if "hydrogen production costs have historically been prohibitive".	the section is improved and the mentioned sentence is removed:"Hydrogen produced from natural gas has been an essential feedstock to the petrochemical sector for decades. In order for hydrogen to support decarbonization, it will need to be produced from low/zero-carbon energy sources or, if not, offset by carbon sequestration. 'Blue' hydrogen would be produced from natural gas through the process of autothermal reforming (ATR) or steam methane reforming (SMR), gasification of biomass (i.e., potential to achieve negative carbon emissions (IRENA 2019d)), combined with carbon capture and storage (CCS) technology, and other processes such as pyrolysis of methane (Sanchez-Bastardo et al., 2020). 'Green' hydrogen can be produced from low/zero carbon energy sources such as renewables, biogas, and nuclear using high temperature reactors (Jaszczur et al. 2016) in electrolysis process (Schmidt et al. 2017a) and thermochemical water splitting (EERE 2020). Recent developments and improvements in hydrogen production technologies in terms of efficiency and capital costs (e.g., PEM and SOEC electrolyzers) (Mayyas et al. 2019) are increasing the viability of hydrogen in low carbon energy systems (Schmidt et al. 2017b). For example, the trajectory needed to limit global warming at 1.5°C could make electrolyzers about 40% cheaper by 2030 (IRENA, 2020). "	Cédric PHILIBERT	Institut Français des Relations Internationales	France
78693	90	8	90	14	recent hydrogen cost reporting and projection by IRENA (https://www.irena.org/publications/2020/Dec/Green-hydrogen-cost-reduction) would be valuable to be added in this section	The following sentence is added:"For example, the trajectory needed to limit global warming at 1.5°C could make electrolyzers about 40% cheaper by 2030 (IRENA, 2020). "	Christian Breyer	LUT University	Finland
55833	90	9	90	11	Recommend deleting "(e.g., SMR) (Committee on Climate Change 2018), and emergence of technologies" and replacing with "(e.g., PEM and SOEC electrolyzers)" using this reference: https://www.nrel.gov/docs/fy19osti/72740.pdf Then, delete the existing "(e.g., mainly electrolyzers, SOEC) SMR has been mature for several decades, but costs of both PEM and SOEC electrolysis have declined".	The following is updated:"Recent developments and improvements in hydrogen production technologies in terms of efficiency and capital costs (e.g., PEM and SOEC electrolyzers) (Mayyas et al. 2019) are increasing the viability of hydrogen in low carbon energy systems (Schmidt et al. 2017b). For example, the trajectory needed to limit global warming at 1.5°C could make electrolyzers about 40% cheaper by 2030 (IRENA, 2020). "	Government of United States of America	U.S. Department of State	United States of America
69677	90	11			You can say costs gets reduced, but what does "more competitive" means? Competitive with what?	The following is updated:"Recent developments and improvements in hydrogen production technologies in terms of efficiency and capital costs and emergence of technologies (e.g., PEM and SOEC electrolyzers) (Mayyas, A.T et al., 2019) for hydrogen production are becoming more competitive compared to other decarbonization pathways (Schmidt et al. 2017b). These technological changes, are increasing the viability of hydrogen. For example, the trajectory needed to limit global warming at 1.5°C could make electrolysers an estimated 40% cheaper by 2030 (IRENA, 2020). "	Cédric PHILIBERT	Institut Français des Relations Internationales	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
5397	90	12	90	12	delete "along with decreasing costs of renewable power". It does not depends of how the lectricity is produced.	The following is updated:"Recent developments and improvements in hydrogen production technologies in terms of efficiency and capital costs and emergence of technologies (e.g., PEM and SOEC electrolyzers) (Mayyas, A.T et al., 2019) for hydrogen production are becoming more competitive compared to other decarbonization pathways (Schmidt et al. 2017b). These technological changes, are increasing the viability of hydrogen. For example, the trajectory needed to limit global warming at 1.5°C could make electrolysers an estimated 40% cheaper by 2030 (IRENA, 2020). "	Michel SIMON	Retraité/ Pdt d'association	France
75861	90	13	90	14	Perhaps a more suitable reference for the cost reduction (in general, not only coupled to offshore wind) and both in the short and long term is [27] [27] https://www.irena.org/publications/2020/Dec/Green-hydrogen-cost-reduction	The reference is added.	Herib Blanco	International Renewable Energy Agency (IRENA)	Germany
52251	90	14	90	14	Reference is unlikely to be objective.	Fixed	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
69681	90	15	90	22	The pyrolysis of natural gas ("methane splitting", "turquoise hydrogen" that does not lead to the formation of CO2, is missing here.	The section is improved as follows:"Hydrogen produced from natural gas has been an essential feedstock to the petrochemical sector for decades. In order for hydrogen to support decarbonization, it will need to be produced from low/zero-carbon energy sources or, if not, offset by carbon sequestration. ‘Blue’ hydrogen would be produced from natural gas through the process of autothermal reforming (ATR) or steam methane reforming (SMR), gasification of biomass (i.e., potential to achieve negative carbon emissions (IRENA 2019d)), combined with carbon capture and storage (CCS) technology, and other processes such as pyrolysis of methane (Sanchez-Bastardo et al., 2020). ‘Green’ hydrogen can be produced from low/zero carbon energy sources such as renewables, biogas, and nuclear using high temperature reactors (Jaszczur et al. 2016) in electrolysis process (Schmidt et al. 2017a) and thermochemical water splitting (EERE 2020). ." This has been invetigated in detail in section 6.4.5.	Cédric PHILIBERT	Institut Français des Relations Internationales	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
69679	90	18	90	19	The level of absorption should not be confused with a reduction figure, as CCS requires more fuel use from the onset.	The section is improved as follows:"Hydrogen produced from natural gas has been an essential feedstock to the petrochemical sector for decades. In order for hydrogen to support decarbonization, it will need to be produced from low/zero-carbon energy sources or, if not, offset by carbon sequestration. ‘Blue’ hydrogen would be produced from natural gas through the process of autothermal reforming (ATR) or steam methane reforming (SMR), gasification of biomass (i.e., potential to achieve negative carbon emissions (IRENA 2019d)), combined with carbon capture and storage (CCS) technology, and other processes such as pyrolysis of methane (Sanchez-Bastardo et al., 2020). ‘Green’ hydrogen can be produced from low/zero carbon energy sources such as renewables, biogas, and nuclear using high temperature reactors (Jaszczur et al. 2016) in electrolysis process (Schmidt et al. 2017a) and thermochemical water splitting (EERE 2020). ." This has been invetigated in detail in section 6.4.5.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
2889	90	19	90	21	Some sources refer to green hydrogen as hydrogen from renewable energy sources and distinguish it fro low-carbon hydrogen.	The section is improved as follows:"Hydrogen produced from natural gas has been an essential feedstock to the petrochemical sector for decades. In order for hydrogen to support decarbonization, it will need to be produced from low/zero-carbon energy sources or, if not, offset by carbon sequestration. ‘Blue’ hydrogen would be produced from natural gas through the process of autothermal reforming (ATR) or steam methane reforming (SMR), gasification of biomass (i.e., potential to achieve negative carbon emissions (IRENA 2019d)), combined with carbon capture and storage (CCS) technology, and other processes such as pyrolysis of methane (Sanchez-Bastardo et al., 2020). ‘Green’ hydrogen can be produced from low/zero carbon energy sources such as renewables, biogas, and nuclear using high temperature reactors (Jaszczur et al. 2016) in electrolysis process (Schmidt et al. 2017a) and thermochemical water splitting (EERE 2020). ." This has been invetigated in detail in section 6.4.5.	Leonardo Barreto	Head of center "EU&International"	Austria

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
18259	90	21	90	22	(Box 6.7) "Hydrogen can also be produced through gasification of biomass with CCS (BECCS), leading to negative carbon emissions". What is the level of confidence / agreement with regards this statement? How are carbon emissions in the production of biomass accounted for in order to achieve negative emissions? Suggest a statement such as this requires further explanation and justification.	The section is improved as follows:"Hydrogen produced from natural gas has been an essential feedstock to the petrochemical sector for decades. In order for hydrogen to support decarbonization, it will need to be produced from low/zero-carbon energy sources or, if not, offset by carbon sequestration. 'Blue' hydrogen would be produced from natural gas through the process of autothermal reforming (ATR) or steam methane reforming (SMR), gasification of biomass (i.e., potential to achieve negative carbon emissions (IRENA 2019d)), combined with carbon capture and storage (CCS) technology, and other processes such as pyrolysis of methane (Sanchez-Bastardo et al., 2020). 'Green' hydrogen can be produced from low/zero carbon energy sources such as renewables, biogas, and nuclear using high temperature reactors (Jaszczur et al. 2016) in electrolysis process (Schmidt et al. 2017a) and thermochemical water splitting (EERE 2020). ." This has been invetigated in detail in section 6.4.5.	Government of United Kingdom (of Great Britain and Northern Ireland)	Department for Business, Energy & Industrial Strategy	United Kingdom (of Great Britain and Northern Ireland)
69683	90	21	90	22	Gasification of biomass must be completed with steam methane reforming to deliver hydrogen	The section is improved as follows:"Hydrogen produced from natural gas has been an essential feedstock to the petrochemical sector for decades. In order for hydrogen to support decarbonization, it will need to be produced from low/zero-carbon energy sources or, if not, offset by carbon sequestration. 'Blue' hydrogen would be produced from natural gas through the process of autothermal reforming (ATR) or steam methane reforming (SMR), gasification of biomass (i.e., potential to achieve negative carbon emissions (IRENA 2019d)), combined with carbon capture and storage (CCS) technology, and other processes such as pyrolysis of methane (Sanchez-Bastardo et al., 2020). 'Green' hydrogen can be produced from low/zero carbon energy sources such as renewables, biogas, and nuclear using high temperature reactors (Jaszczur et al. 2016) in electrolysis process (Schmidt et al. 2017a) and thermochemical water splitting (EERE 2020). ." This has been invetigated in detail in section 6.4.5.	Cédric PHILIBERT	Institut Français des Relations Internationales	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
55835	90	25	90	31	This content is a little misleading and incorrect. Recommend rewording to: "Distribution of hydrogen long distances is currently conducted using tube trailers, liquid tankers, and pipelines. Chemical carriers are an emerging method of large-scale distribution and use, and may also be compatible with existing infrastructure for natural gas and petroleum. Use of existing pipeline infrastructure for gaseous hydrogen distribution is feasible, but will be limited by the potential for gaseous hydrogen to affect the durability of steel (i.e., "hydrogen embrittlement"). Ongoing R&D efforts, such as the U.S. DOE's H-Mat consortium, are currently working to address these challenges."	The following is updated:"Hydrogen faces a number of barriers and challenges. The potential role of hydrogen in future energy systems depends in large part on its competitiveness and the infrastructural needs to deploy it at relevant scales (IRENA 2019d; DENA 2017). Global deployment of hydrogen (e.g. Muratori et al. 2018; Gumber and Gurumoorthy 2018) through the existing gas infrastructures (e.g., within a country) may not completely feasible. However, for example, 11 Gas Transmission Companies have now proposed to develop a European hydrogen backbone based on re-using gas pipelines (estimation of 0.13 €/kg/1000km for hydrogen transport (Wang et al, 2020)). Beside physical barriers, such as steel embrittlement and degradation of seals, reinforcements in compressor stations, valves, new pipelines would be required (Gasunie 2019). For longer distances (e.g., through continents), hydrogen (mainly through ammonia) can be transported as liquid gas, which is well-known world-wide. Short-distance transport within district areas, can be carried out with existing gas infrastructure (e.g., Iron Main Programme in the UK (CCC 2018)), while some hydrogen storage may be required."	Government of United States of America	U.S. Department of State	United States of America
71731	90	25	90	28	This statement is far too pessimistic. While it is true that there are limitations in steel pipelines, this does not apply to PE pipelines, which are already wide-spread (see e.g. Ball and Wietschel 2009: The hydrogen economy). Moreover, other parts of the infrastructure can be retrofit. So it will require some efforts, but it also considered in several countries (UK, Netherlands, Germany) to convert part of the existing gas infrastructure to hydrogen.	The following is updated:"Hydrogen faces a number of barriers and challenges. The potential role of hydrogen in future energy systems depends in large part on its competitiveness and the infrastructural needs to deploy it at relevant scales (IRENA 2019d; DENA 2017). Global deployment of hydrogen (e.g. Muratori et al. 2018; Gumber and Gurumoorthy 2018) through the existing gas infrastructures (e.g., within a country) may not completely feasible. However, for example, 11 Gas Transmission Companies have now proposed to develop a European hydrogen backbone based on re-using gas pipelines (estimation of 0.13 €/kg/1000km for hydrogen transport (Wang et al, 2020)). Beside physical barriers, such as steel embrittlement and degradation of seals, reinforcements in compressor stations, valves, new pipelines would be required (Gasunie 2019). For longer distances (e.g., through continents), hydrogen (mainly through ammonia) can be transported as liquid gas, which is well-known world-wide. Short-distance transport within district areas, can be carried out with existing gas infrastructure (e.g., Iron Main Programme in the UK (CCC 2018)), while some hydrogen storage may be required."	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
81001	90	25	90	28	Here it is stated that 'global deployment of hydrogen through the existing gas infrastructures is not feasible' This statement is not true. Extensive research and testing is already done in re-using natural gas pipelines for hydrogen transport, although some adaptations needs to be done, especially in the transport pipeline system it is necessary to retrofit or replace the compressors and sometimes they have to replace part of the pipelines that are already in use for over 30 years, due to some cracking or degradation. But essentially it is technically not complicated, can be realised fast and relatively cheap. That is what you can read in the reports from Gasunie, DNV-GL, KIWA and others. Therefore 11 Gas TSO's have now proposed to develop an European Hydrogen backbone based on re-using gas pipelines. They estimate that hydrogen transport cost are about 0.13 Euro/kg H2/1000km which is 0.003 Euro/kWh H2 (HHV)/1000 km. See also comment 11	The following is updated:"Hydrogen faces a number of barriers and challenges. The potential role of hydrogen in future energy systems depends in large part on its competitiveness and the infrastructural needs to deploy it at relevant scales (IRENA 2019d; DENA 2017). Global deployment of hydrogen (e.g. Muratori et al. 2018; Gumber and Gurumoorthy 2018) through the existing gas infrastructures (e.g., within a country) may not completely feasible. However, for example, 11 Gas Transmission Companies have now proposed to develop a European hydrogen backbone based on re-using gas pipelines (estimation of 0.13 €/kg/1000km for hydrogen transport (Wang et al, 2020)). Beside physical barriers, such as steel embrittlement and degradation of seals, reinforcements in compressor stations, valves, new pipelines would be required (Gasunie 2019). For longer distances (e.g., through continents), hydrogen (mainly through ammonia) can be transported as liquid gas, which is well-known world-wide. Short-distance transport within district areas, can be carried out with existing gas infrastructure (e.g., Iron Main Programme in the UK (CCC 2018)), while some hydrogen storage may be required."	Ad van Wijk	TU Delft	Netherlands
51419	90	28			In the UK, H2 distribution via existing polyethylene pipes may be possible see https://www.northerngasnetworks.co.uk	We appreciate the comment. The following is updated:"Hydrogen faces a number of barriers and challenges. The potential role of hydrogen in future energy systems depends in large part on its competitiveness and the infrastructural needs to deploy it at relevant scales (IRENA 2019d; DENA 2017). Global deployment of hydrogen (e.g. Muratori et al. 2018; Gumber and Gurumoorthy 2018) through the existing gas infrastructures (e.g., within a country) may not completely feasible. However, for example, 11 Gas Transmission Companies have now proposed to develop a European hydrogen backbone based on re-using gas pipelines (estimation of 0.13 €/kg/1000km for hydrogen transport (Wang et al, 2020)). Beside physical barriers, such as steel embrittlement and degradation of seals, reinforcements in compressor stations, valves, new pipelines would be required (Gasunie 2019). For longer distances (e.g., through continents), hydrogen (mainly through ammonia) can be transported as liquid gas, which is well-known world-wide. Short-distance transport within district areas, can be carried out with existing gas infrastructure (e.g., Iron Main Programme in the UK (CCC 2018)), while some hydrogen storage may be required."	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
51421	90	28			/wp-content/uploads/2017/04/H21-Executive-Summary-Interactive-PDF-July-2016-V2.pdf	Related to the previous comment	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
7891	90	29	90	29	hydrogen (mainly through ammonia) can be transported as liquid gas -- this needs more clarity - is it ammonia - and then - is it liquid ammonia or gaseous ammonia - or liquid or gaseous hydrogen?	The detail of hydrogen transport is presented in secion 6.4.5	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
52255	90	30	90	31	Sentence starting with "But in…." makes no sense.	Not relevant to this section	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
17437	90	32	90	32	"Improvements in hydrogen use are emerging quickly." I cannot agree. Hydrogen is mentioned as a"promising" energy carrier for 2 decades with rather small improvements during that time. Huge hydrogen industry is still relying on hydrogen from the fossil natural gas and coal. Hydrogen cars are being developed for 2 decades - and they are invisible...	This section is updated/improved:"There is significant development in technologies that use hydrogen for generation of electricity and transport. General Electric (GE) gas turbines are now running on fuels that contain a 5%-95% hydrogen by volume (GE 2020). Gas turbines could be able to operate completely on hydrogen by 2030 (Siemens 2019). The Japanese government has invested in hydrogen fuel infrastructure (METI 2017) to support hydrogen-based fuel cell vehicles as well as hydrogen combustion in thermal power plants (JERA, 2020). In Germany two hydrogen fuel cell powered trains are operating since 2018 (Cummin 2018) and in the ZEFER project (ZEFER 2020), 180 fuel cell vehicles will be deployed by 2022 in Europe to investigate the business case for hydrogen vehicles. There are also safety issues, concerns associated with flammability (Nilsson et al. 2017), toxicity (Bicer and Dincer 2017; EPA 2001), and storage (Eberle et al. 2009) (section 6.4.5)."	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
55837	90	32	90	41	This paragraph has a lot of content, and may be confusing as written. Since the main focus is on turbines, would be better to remove the content on fuel cells and ammonia toxicity; those parameters are addressed later in the document.	The section is improved siginifcantly	Government of United States of America	U.S. Department of State	United States of America
64183	90	32	90	41	Please also see section 10.3.2.1 in chapter 10	Checked. In here we provided the big picture in the context of hydrogen economy, while in that section the fuel cell vehicles are provided in more detail.	Minal Pathak	WGIII TSU, Ahmedabad University	India

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
45519	90	33	90	34	Maybe more precise to say that now already several of Siemens' gas turbines run on 100% H2 (and they want to expand to more GTs towards 2030)	There may be trials for 100% hydrogen based gas turbines. However a commersialised 100% hydrogen based gas turbines is projected until 2030. The section is improved:"There is significant development in technologies that use hydrogen for generation of electricity and transport. General Electric (GE) gas turbines are now running on fuels that contain a 5%-95% hydrogen by volume (GE 2020). Gas turbines could be able to operate completely on hydrogen by 2030 (Siemens 2019). The Japanese government has invested in hydrogen fuel infrastructure (METI 2017) to support hydrogen-based fuel cell vehicles as well as hydrogen combustion in thermal power plants (JERA, 2020). In Germany two hydrogen fuel cell powered trains are operating since 2018 (Cummin 2018) and in the ZEFER project (ZEFER 2020), 180 fuel cell vehicles will be deployed by 2022 in Europe to investigate the business case for hydrogen vehicles. There are also safety issues, concerns associated with flammability (Nilsson et al. 2017), toxicity (Bicer and Dincer 2017; EPA 2001), and storage (Eberle et al. 2009) (section 6.4.5).".	Kornelis Blok	Delft University of Technology	Netherlands
55839	90	33	90	33	Recommend deleting the sentence "Gas turbines could be able to …" Turbines are already able to operate at up to 100% H2.	There may be trials for 100% hydrogen based gas turbines. However a commersialised 100% hydrogen based gas turbines is projected until 2030. The section is improved:"There is significant development in technologies that use hydrogen for generation of electricity and transport. General Electric (GE) gas turbines are now running on fuels that contain a 5%-95% hydrogen by volume (GE 2020). Gas turbines could be able to operate completely on hydrogen by 2030 (Siemens 2019). The Japanese government has invested in hydrogen fuel infrastructure (METI 2017) to support hydrogen-based fuel cell vehicles as well as hydrogen combustion in thermal power plants (JERA, 2020). In Germany two hydrogen fuel cell powered trains are operating since 2018 (Cummin 2018) and in the ZEFER project (ZEFER 2020), 180 fuel cell vehicles will be deployed by 2022 in Europe to investigate the business case for hydrogen vehicles. There are also safety issues, concerns associated with flammability (Nilsson et al. 2017), toxicity (Bicer and Dincer 2017; EPA 2001), and storage (Eberle et al. 2009) (section 6.4.5).".	Government of United States of America	U.S. Department of State	United States of America
45517	90	34	90	34	Simens should be: Siemens	Fixed	Kornelis Blok	Delft University of Technology	Netherlands
66721	90	34	90	35	I think it may be worth to mention also recen policy support/plans published by the European Commission and some Member States (e.g. Germany and France)	The Japansese and German strategies are provided here. Furthermore, the Australian strategy is presented in detail in section 6.4.5	Chiodi Alessandro	E4SMA	Italy
50075	90	35	90	35	METI, not Meti?	Fixed	Masahiro Sugiyama	University of Tokyo	Japan

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
69685	90	35	90	37	This is a very narrow description of the Japanese Hydrogen Strategy. The largest foreseen consumption of Hydrogen in Japan in the coming decades is for combustion in power thermal plants, starting with ammonio co-combustion in coal plants. See GoJ? 2017 Basic Hydrogen Strategy (https://www.meti.go.jp/english/press/2017/1226_003.html), and Jera 2020 NZE strategy (https://www.jera.co.jp/english/corporate/zeroemission)	The sentece is updated:"The Japanese government has invested in hydrogen fuel infrastructure (METI 2017) to support hydrogen-based fuel cell vehicles as well as hydrogen combustion in thermal power plants (JERA, 2020). " due to space limit we were not able to expand further.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
69687	90	35	90	37	Is a project concernant 180 vehicles worth being quoted here?	Since it is a demonstration towards hydrogen economy, presenting this project is approporate	Cédric PHILIBERT	Institut Français des Relations Internationales	France
17439	90	37	90	38	"Hyundai is aiming to produce 700,000 fuel-cell based engines by 2030 (Powerlinks 2018). " Not a live plan anymore. Reference: https://www.forbes.com/sites/johnkang/2020/02/28/as-hyundai-races-toward-electric-vehicles-hydrogen-powered-cars-take-a-backseat/ .	Thanks for this. Removed	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
51423	90	39			viable. Though two hydrogen fuel cell powered trains are running in Germany since 2018. see https://www.cummins.com	Added to the text.	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
51425	90	39			/news/2020/02/28/power-passenger-trains-how-hydrogen-can-revolutionize-railway-operations-europe	Related to the previous comment	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
81003	90	39	90	41	At the end of box 6.7 The Hydrogen Economy it is stated 'There are also safety concerns associated with flammability, toxicity and storage in the context of hydrogen carriers and use in appliances' Safety issues, (not concerns), have to be dealt with for every energy source or carrier, but hydrogen does not have more or severe safety issues then natural gas or even electricity. First of all hydrogen is not toxic. Hydrogen is indeed flammable, which is good because otherwise you could not use it for combustion. However, it is flammable at lower temperature, with lower ignition energy and within a broader range of hydrogen/air mixtures than natural gas, which suggests it is less safe than natural gas. But due to the fact that hydrogen is the lightest and smallest element it raises in air with a speed of 72 km/hr (20 m/s) and therefore has disappeared before it has the right mixture to ignite. Research by especially KIWA about hydrogen safety by using it in houses, shows that risks of explosion in houses due to hydrogen leakage and fire are equal or lower than for natural gas. In fact hydrogen applied in houses is safer than natural gas, because most of incidents and mortalities are by carbonmonoxide poisoning, which is not the case when burning hydrogen. When using hydrogen like natural gas in houses, there is no storage, is is supplied by a pipeline. Such a sentence at the end of this box is misleading, partly not true and suggestive.	Due to space limit we were not able to expand here further. In section 6.4.5, these issues are presented in detail.	Ad van Wijk	TU Delft	Netherlands

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
2893	90	43	92	17	Digitalisation offers the potential to increase energy efficiency through a combination of technologies that gather and analyse data and, based on this data analysis, optimise energy use in real time. Digitalization of the economy through technologies like tele-working, e-mobility, intelligent building management systems, industry 4.0 etc. can drive to a reduction in energy demand (e.g. TWI2050 - The World in 2050 (2019). The Digital Revolution and Sustainable Development: Opportunities and Challenges. Report prepared by the World in 2050 initiative. International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria). At the same time, the total electricity demand of information and communications technologies (ICTs) can increase substantially, making green growth of ICT technology essential. Also, some digital technologies could induce rebound effects that could lead to an increase in overall energy use. These impacts must be carefully examined and measures to prevent them implemented.	Digitalization aspects are discussed in section 6.4.3.3, so we refer the reader to that section.	Leonardo Barreto	Head of center "EU&International"	Austria
64335	90	43	92	17	This section should also discuss using energy more effectively, i.e., using the right type of energy for the application and this particularly applies to building space heating. Building space heating is a low-quality form of energy by virtue of the requirement for a room temperature at 21°C or thereabouts; there is little else useful you can do with air at this temperature other than keep comfortable. In contrast, natural gas, which is the dominant fuel used to meet space heating demands, is regarded as high-quality form of energy. The same applies to other emerging alternative gases such as biomethanes and hydrogen. This is because such gases typically burn with a flame temperature of around 2000°C that can be used in many useful and profitable ways such as electricity generation, mechanical drives (engines/turbines), chemical processes and industrial applications. The concept of 'energy quality' is therefore a measure of the ease at which one form of energy can be converted to useful work (e.g., mechanical drive) or to another form of energy (e.g., steam). High-quality energy is easily converted to work or to a lower quality energy, whereas converting low quality energy to work or a higher quality form may be inefficient, difficult or impossible. High quality energy can be used to perform high quality tasks as well as low quality tasks, low quality energy can only be practically used to perform low quality tasks. The use of a gas boiler for space heating (a high-quality energy source used for a low-quality energy demand), although it may be an efficient boiler minimising the gas needed, is a very wasteful technology in that much of the potential of the gas used is unutilised and permanently lost. The use of a gas boiler for space heating is therefore ineffective in utilising the potential of high-quality energy resources which may in itself be finite, scarce and expensive. The level of boiler effectiveness can be calculated to be as low as 4.8% . The same argument applies to electrification of heat by resistive heating.	Good point. Given the space constraints we can't add text without removing existing text, but we added: "Space heating may rely on fuels/carriers that have very high energy quality (such as natural gas, H2, biomethane, or electrification of heat by resistive heating), where even with high technology efficiency, much of the energy content will be wasted."	Peter North	Imperial College (part-time PhD student) /Calorem Ltd	United Kingdom (of Great Britain and Northern Ireland)
4187	90	41	90	41	Flammability concerns may also further limit hydrogen fuel large-scale use in extremely hot, arid equatorial and Middle Eastern countries. Alternative PV grids will become more viable in these localities.	Due to space limit we were not able to expand here further. In section 6.4.5, these issues are presented in detail.	Neil M. Mulchan	Adventure Physics, LLC	United States of America
63179	90	44	91	18	Challenges to implementation of energy efficiency measures include split incentives across landlords, tenants, and real estate developres, as well as a need to educate consumers.	Agreed, but these and other issues related to energy efficiency deployment are detailed in the demand chapter, and given the space constraints we will not repeat that here.	Jennifer Sklarew	George Mason University	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
79669	90	44	90	46	Since reducing energy consumption is central in order to have the potential to deliver the energy needed, this paragraph could be emphasized. Sr-trategy to reduce the reduction of energy services are essential. Therefore I suggest: " energy efficiency improvments, strategy that reduce demand of energy services such as reducing transportation of persons and freight, material ressources, urban planning..., and load curtailment; " You could add the following reference J M Allwood, J M Cullen, Sustainable materials without hot air, Cambridge 2015. You coud add the following to illustrate the continuous loss of energy at the level of uses on the bases of US energy structure: Chart 1, Net zero carbon cities. An integrated approach. World economic forum. january 2021.	We changed the sentence slightly, but kept the focus on energy.	Marc Daras	CentraleSupelecAlumni	France
48143	91	1	91	1	"Net zero energy systems will use less energy and use it more efficiently than those of today" Please discuss the reat demand reduction that occurs automatically due to electrification and providing that electricity with clean, renewable energy. Specifically, the paper Jacobson, M.Z., M.A. Delucchi, M.A. Cameron, S.J. Coughlin, C. Hay, I.P. Manogaran, Y. Shu, and A.-K. von Krauland, Impacts of Green New Deal energy plans on grid stability, costs, jobs, health, and climate in 143 countries, One Earth, 1, 449-463, doi:10.1016/j.oneear.2019.12.003, 2019 finds that such a transition decreases end-used demand 57% due to 5 reasons: the efficiency of electric transportation over internal combustion; the efficiency of heat pumps over fossil heaters; the efficiency of electrified industry; eliminating mining of fossil fuels and uranium; and small end-use energy efficiency improvements beyond BAU. Global demand reductions upon electrification and providing the electricity with clean, renewable energy were first quantified by Jacobson, M.Z., and M.A. Delucchi, A path to sustainable energy by 2030, Scientific American, November 2009;	We added "strategies that decrease energy consumption or demand for energy services" to encompass some of the energy conservation strategies. We already include the importance of electrification in the sentence "The gains will instead come from a transition to electrification and hydrogen. " Regarding demand and energy consumption levels under net zero, we already include the ranges found accross papers from the review and analysis of multiple models from DeAngelo et al.	Mark Jacobson	Stanford University	United States of America
7893	91	6	91	6	Newly published research suggests that the rebound effect reduces the impact of energy efficiency: Quoting from the paper: Evidence from 33 studies suggests economy-wide rebound effects typically exceed 50%. Quoting from the paper: By neglecting these effects, global models may underestimate future energy demand. https://www.sciencedirect.com/science/article/pii/S1364032121000769?via%3Dihub	We already include the following statement "tructure, endowed natural resources, and consumer preferences, policies and regulations. In addition, Eenergy efficiency and other demand-side strategies represent such a large set of technologies, strategies, policies, market and consumers' responses and policies that aggregate measures can be difficult to define". REbound effects are captures under those uncertainties. Saunders et al. paper, which we cite, already discusses the outcomes of energy efficiency and the role of rebound, so for sake of space contrainsts, we will not add more here. Note that the demand chapter includes the discussions of rebound.	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
61833	91	19	91	25	"Energy consumption will increase over time despite energy efficiency improvements due to population growth and development implying we will need more low-carbon energy sources in place with resources and sites that are less efficient (DeAngelo, 2021)." This statement has serious discrepancy with the chosen Illustrative Pathway scenarios in Chapter 3, Figure 3.14 that show no increase in the final primary energy use and even show a significant reduction. The Illustrative Pathways and their assumptions should be fixed to be more in line with the above from (DeAngelo, 2021).	All our statement are for net scenrio scenarios, not across all scenarios.	Rauli Partanen	Think Atom	Finland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
65871	91	19	91	25	Energy consumption will increase over time despite energy efficiency improvements due to population growth and development implying we will need more low-carbon energy sources in place with resources and sites that are less efficient (DeAngelo, 2021)." Please clarify the discrepancy between this statement and the chosen Illustrative Pathway scenarios in Chapter 3, Figure 3.14 that show no increase in the final primary energy use but even a significant reduction. Correspondingly, fix the assumptions in the Illustrative Pathway scenarios.	All our statement are for net scenrio scenarios, not accross all scenarios.	Eero Hirvijoki	Aalto University	Finland
17533	91	24	91	26	duplicated sentence	Duplicate removed.	Alaa Al Khourdajie	IPCC	United Kingdom (of Great Britain and Northern Ireland)
27735	91	24	91	25	Delete "DeAngelo (2021), review the outputs for 177 net-zero energy systems scenarios", the sentence is incomplete and a repetition of the following paragraph.	Duplicate removed.	Eleni Kaditi	Organization of the Petroleum Exporting Countries, OPEC	Austria
51427	91	24			energy sources in place with resources and sites that are less efficient- why?	We removed the second part of the sentence	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
65873	91	26	91	38	The entire paragraph needs rephrasing and clarification. For example, "Across regions, energy use per capita varies more broadly, and many countries use far more energy per capita than today as their incomes increase. Global final energy use per unit of economic output ranges from 0.7 to 2.2 EJ/USD trillion (median: 1.4,), as compared to 5 EJ/USD trillion in 2018." This statement is not very clear to the reader. It states that many countries will use far more energy than today but still globally the energy use per GDP will plummet from 5 to 1.4 EJ/USD trillion. Rephrase the entire paragraph and deliver a clear message. Currently it appears to be in conflict with itself.	We have re-writen that paragraph.	Eero Hirvijoki	Aalto University	Finland
69689	91	42	91	43	There are important efficiency gains attached to electrification of transports, but the gains attached to the use of hydrogen in transports would be very limited or null. At best, efficiency of electricity to mobility via hydrogen will be ~30% (70% electrolysis, 80% compression, transport and distribution, 60% fuel cells, 90% electronics and motorisation), which is about the same as that of internal combustion engines. (several studies whos hydrogen efficiency closer to 25%)	We changed the setence to "GHG emissions mitigation The gains will instead come from a transition to electrification, and hydrogen or synthetic fuels produced with low carbon energy sources or processes ."	Cédric PHILIBERT	Institut Français des Relations Internationales	France
2891	91	43	91	44	the combination of Autonomous driving, Connectivity through the Internet-of-Things (IoT), Electrification and Shared mobility (so-called ACES) has potental increase efficiency and reduce associated GHG emissions, provided rebound effects can be mitigated. These technologies provide opportunities to improve mobility and reduce car ownership, car traffic and parking needs but should be integrated with public transport to obtain better efficiency gains	These aspect are already cited in the paragraph, so we will not make changes to the current text.	Leonardo Barreto	Head of center "EU&International"	Austria
2699	91	44	92	3	Where are the references backing up these statements?	These have now been added.	Jan Wohland	ETH Zurich	Switzerland
69691	91	48	92	1	Drones would probably be more efficient than hydrogen vehicles.	We removed the comparison to hydrogen and electrified vehicles.	Cédric PHILIBERT	Institut Français des Relations Internationales	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
48145	92	1	92	2	"There are few detailed archetypes of integrated energy systems that provide services with zero- or net negative CO2 emissions." There are actually several such papers. Here is one recent one, where sector coupling among 6 sectors (electricity, transportation, building energy, industry, agriculture/forestry/fishing, and the military) was simulatied in a 100% clean, renewable energy system in 143 countries: Jacobson, M.Z., M.A. Delucchi, M.A. Cameron, S.J. Coughlin, C. Hay, I.P. Manogaran, Y. Shu, and A.-K. von Krauland, Impacts of Green New Deal energy plans on grid stability, costs, jobs, health, and climate in 143 countries, One Earth, 1, 449-463, doi:10.1016/j.oneear.2019.12.003, 2019	We included a reference to this paper.	Mark Jacobson	Stanford University	United States of America
66723	92	2	92	3	You mention: 'In other sectors, such as air travel and marine transportation will may rely on biofuels'. I think also hydrogen shall be mentioned as potential option.	We changed the sentence to: "OIn other sectors, such as air travel and marine transportation will may rely on alternative biofuels (such as biofuels, synthetic fuels, or ammonia produced with zero carbon energy source) "	Chiodi Alessandro	E4SMA	Italy
71733	92	2	92	3	'marine transportation will may rely on biofuels' - why not clean renewable energy?	We changed the sentence to: "OIn other sectors, such as air travel and marine transportation will may rely on alternative biofuels (such as biofuels, synthetic fuels, or ammonia produced with zero carbon energy source) "	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
55841	92	3	92	3	The sentence contains WILL and MAY consectutively, but the choice of word is important for the meaning of the overall sentence.	We edited these paragraph, and use will or may depending on the confidence.	Government of United States of America	U.S. Department of State	United States of America
69693	92	3	92	3	There would probably never be enough sustainably harvested biofuels to support air travel and marine transportation, thus leaving room for e-kerosene (or full compensation with CDR) for aviation, and green ammonia as fuel for marine transportation.	We changed the sentence to: "OIn other sectors, such as air travel and marine transportation will may rely on alternative biofuels (such as biofuels, synthetic fuels, or ammonia produced with zero carbon energy source) "	Cédric PHILIBERT	Institut Français des Relations Internationales	France
47055	92	4	92	12	There should be a greater emphasis here on using energy-efficient alternatives to current high-GWP refrigerants for cooling systems in buildings (among others), considering it was mentioned in a previous section how cooling would be one of the major sources of higher energy consumption in the next few decades.	This could be a focus on chapter 9. Due to space constraints we will not add more here.	John Leo Algo	Living Laudato Si' Philippines	Philippines
69695	92	4	92	7	Any literature in support of the inclusion of "smaller floor areas", which goes against current trends, and may not be a requirement for NZE. For example, Grubler et alii. 2018 (op.cit.) in their low energy demand scenario assume residential floor space of 30 m2 per capita globally by 2050, which is the current average in industrialised countries, and three times higher than the minimum acceptable for a decent standard of living.	See Chapter 9	Cédric PHILIBERT	Institut Français des Relations Internationales	France
84361	92	5	92	5	The global efficiency of smart building is often questionable regarding the ICT efficiency of 10^-8 [Semiconductor Industry Association/Semiconductor Research Corporation : "Rebooting the IT revolution" (Sept. 2015): https://www.semiconductors.org/resources/rebooting-the-it-revolution-a-call-to-action-2/] beyond the basic abatements of energy efficiency.	We changed to smart controls, and made the statement less strong. Note that this summarizes chapter 9 statements.	Vincent MAZAURIC	Schneider Electric	France
69697	92	7	92	7	The use of hydrogen in buildings is very hypothetical given much lower efficiency compared to electrification (via heat pumps) and the risks associated with the possibility of hydrogen leaks in closed space, very low flammability levels and no detection by human sense	We added the word "potentially" before hydrogen to reflect those risks and efficiency.	Cédric PHILIBERT	Institut Français des Relations Internationales	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
69699	92	7	92	9	The opposite holds true: using electricity is a more efficient process than using natural gas for both heating and cooking. Heating with electricity-driven heat pumps exhibit an apparent "efficiency" of 300% (seasonal performance factor of 3 or more, that more kWh heat are brought inside than the kWh of electrical consumption), vs. apparent "efficiency" of 110% for the best condensing natural gas boilers (in truth efficiency of less than 1 if measured on HHV rather than LHV). For cooking the difference can be even greater: induction cooktops show higher efficency (~80%) than gas-fired cook-tops (~50%) and, more importantly, the best electric cooking devices, the Electric Pressure Cookers, reduce the energy consumption further by a factor 2 to 4 (depending on the length of cooking) due to 1) pressure reducing cooking times; 2) total insulation reducing heat losses; 3) integration of induction heating. See, e.g. Couture T. and D. Jacobs, 2019, Beyond Fire, World Future Council - Hivos.	The efficiency conversions accounted for here are primary energy to energy services. Several of the examples listed in the comment are only refering to device level efficiency. Regardless, we revised the sentence as "The use of electricity for heating and cooking may often be is a often less a less efficient process at converting primary energy to energy services than using natural gas (i.e., new fuels or energy carriers does not equate with more efficiency)."	Cédric PHILIBERT	Institut Français des Relations Internationales	France
51429	92	8			electricity for heating and cooking is a less efficient process than using natural gas ?Efficiency of heat pumps for heating?	we revised the sentence as "The use of electricity for heating and cooking may often be is a often less a less efficient process at converting primary energy to energy services than using natural gas (i.e., new fuels or energy carriers does not equate with more efficiency)."", as indeed there are some combinations of fuels-technologies such as heat pumps where this does not apply.	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
55843	92	8			The statement "The use of electricity for heating and cooking is a less efficient process than using natural gas" is not necessarily true. It is correct when using electricity produced by fossil power plants, but it may not be correct if using power from renewable energy, since the efficiency losses are then primarily in T&D and may only be roughly 6% (unless one wants to get into the efficiency losses going from solar photons to PV electrons, etc.). Cooking using a microwave, even with fossil electricity, may also be more efficient than using natural gas in many cases. A more useful argument could be made on the total cost to cook using electricity versus fuels, but including an appropriate cost for the associated carbon emissions.	Note that this pertains to conversion from primary energy to energy service, and even with renewables, there will be losses given the ranges of efficiency for wind and solar, for example (i.e., we are refering to what you have in parenthesis in your comment). To clarify, we changed the sentence to: "The use of electricity for heating and cooking may often be is a often less a less efficient process at converting primary energy to energy services than using natural gas (i.e., new fuels or energy carriers does not equate with more efficiency)."	Government of United States of America	U.S. Department of State	United States of America
2701	92	9	92	11	Where are the references backing up these statements?	Changed from "will" to "would" and reinforced that this is under net zero energy systems.	Jan Wohland	ETH Zurich	Switzerland
71735	92	10	92	12	use more careful language for such uncertain statement about the future.	Changed from "will" to "would" and reinforced that this is under net zero energy systems.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
69701	92	13	92	17	It should be more strongly underlined that the key to decarbonisation of industry is electrification based on renewable electricity generation, completed with some other measures. See e.g. Philibert, C. 2017, Renewable Energy for Industry, IEA Insight Papers; Madeddu, 2020, op. cit.	We added "Electrification and brealtrougth processes" before "Breakthrough processes"	Cédric PHILIBERT	Institut Français des Relations Internationales	France
74855	92	15	92	15	H2 should be H2	Corrected	Government of Kenya	Kenya Meteorological Service	Kenya
10667	92	16	92	16	Heap pumps? Possibly heat pumps.	Corrected	Philippe Waldteufel	CNRS	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
18261	92	18	93	29	(Section 6.6.2.6) This section lacks references to levels of confidence / agreement.	We include a confidence statement at the beginning of the second paragraph.	Government of United Kingdom (of Great Britain and Northern Ireland)	Department for Business, Energy & Industrial Strategy	United Kingdom (of Great Britain and Northern Ireland)
66727	92	19	93	29	I find the scope of this section a bit unclear. It starts citing possible interactions of energy systems components in a net zero world (very relevant point). Then it turns on a discussion over methodological approaches to assess/analyse these interactions. I don't find this latter part so relevant in the context of the chapter (unless moved to a box or a specific methodology section)	Our aim here is to characterize the knowledge base about net-zero systems, and given the limited number of such systems in the real world, we rely heavily on the systems modeling literature. So it becomes important to provide context about this literature, as we have also done elsewhere in the chapter.	Chiodi Alessandro	E4SMA	Italy
52253	92	20	92	22	Ignores pricing as an option instead of planning.	We added a phrase at the end of the first paragraph: "...appropriate price signals to align incentives and to coordinate investments and operations."	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
55845	92	21	92	21	What are "lumpy" costs? This phrase is not defined in the text.	We removed "lumpy" from this sentence.	Government of United States of America	U.S. Department of State	United States of America
2895	92	26	92	28	Suggest to mention that the Europen Union has implemented a Governance Mechanism for climate and energy (Regulation 2018/1999 on the Governance of the Energy Union and Climate Action. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018R1999&from=EN). The Governance Regulation integrates strategic planning and reporting on the implementation of climate and energy policies (through integrated National Energy and Climate Action Plans), promotes coordination between actors responsible for energy and climate policy, fosters a multi-level energy dialogue in Member States and supports breaking silos across policies and sectors, across government departments, with stakeholders and the public, and cross-border. The Governance Regulation intents to facilitation regional cooperation, which is key to the achievement of the objectives of the Energy Union in a cost-optimal manner.	An excellent point. While these topics are interesting and important, space limits prevent us from addressing them in greater detail here.	Leonardo Barreto	Head of center "EU&International"	Austria
69703	92	41	92	41	Daily would be more appropriate here than diurnal	We changed "diurnal" to "daily".	Cédric PHILIBERT	Institut Français des Relations Internationales	France
78697	92	42	92	48	indeed, that's the clear finding of Bogdanov et al. (https://www.sciencedirect.com/science/article/pii/S0306261920316639) in hourly resolution, technology-rich and highly sector-coupled analysis	Good to see agreement across a range of studies.	Christian Breyer	LUT University	Finland
43613	93	1	93	1	Replace "archetypes" with "paradigms"	We are using "archetypes" across different sections of the chapter for consistency.	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy
70137	93	7			(Creutzig et al. 2019b). However, attaining even 1Gt of CO2 capture and transport using DAC would entail a CO2 pipeline capacity larger than the 2017 petroleum pipeline system (Mac Mac Dowell et al 2017). https://www.nature.com/articles/nclimate3231	Good point. We already include a reference to infrastructure challenges associated with net-zero pathways in the first paragraph of this subsection.	Rayner Andersen	Department of Fisheries and Oceans	Canada

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
70139	93	8			Given the requirements of scenarios which depend on higher rates of DAC usage, the large scale of infrastructure buildout could be a significant barrier to operation at scale. “Given that CCS is expected to account for the mitigation of approximately 14–20% of total anthropogenic CO2 emissions, in 2050 the CCS industry will need to be larger by a factor of 2–4 in volume terms than the current global oil industry.” (Mac Dowell et al 2017))	Good point. We already include a reference to infrastructure challenges associated with net-zero pathways in the first paragraph of this subsection.	Rayner Andersen	Department of Fisheries and Oceans	Canada
24981	93	9	93	21	Indeed, new types of modelling can prove useful to accelerating the energy tranisiton. A large volume of studies exists demonstrating that both net zero and 100% renewable scenarios are technologically and economically feasible (e.g. https://doi.org/10.1016/j.energy.2019.03.092, https://doi.org/10.1016/j.energy.2008.04.003, https://doi.org/10.1016/j.apenergy.2020.116273, https://doi.org/10.1016/j.apenergy.2010.03.001). The key barrier then lies in the political dimension. Socio-technical energy transition models can help address this. It would be helpful if this section of Chapter 6 supported further research in this domain, which is also connected multi-level models, integrating high-level system boundaries with local solutions and vice versa. This perspective on connecting current dominant practices with radical future visions and short-term measures should be given greater prominence in this summary. Key papers advocating for socio-technial models https://doi.org/10.1016/j.techfore.2015.07.017 https://doi.org/10.1016/j.erss.2018.10.021 https://doi.org/10.1016/j.erss.2020.101559 https://doi.org/10.1016/j.erss.2018.12.010 Bergman, N, Haxeltine, A, Whitmarsh, L, Köhler, J, Schilperoord, M.P, & Rotmans, J. (2008). Modelling socio-technical transition patterns and pathways. Journal of Artificial Societies and Social Simulation: an inter-disciplinary journal for the exploration and understanding of social processes by means of computer simulation, 11(3), 1–32. Retrieved from http://hdl.handle.net/1765/19247	While these topics are interesting and important, space limits prevent us from addressing them in greater detail here.	Emil Beemer	Dutch Research Institute For Transitions, Erasmus University Rotterdam	Netherlands

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
28393	93	9	93	21	Very important paragraph. I think by now the number of net-zero or 100% RE studies have showed both are techno-economically feasable options. The current stagnation comes from policy makers and individuals unaware of which choices and policy measures to make right now under their local circumstances to achieve these high-level targets. A new area of modelling is comming up called socio-technical energy transuittoin models which adress these points. The report should advocate for further research in this domain, also connect multi-level models, integrating high-level system boundaries with local solutions and the other way around. And when doing so focus in analysis on identifying critical "Sensitive Intervention Points" which can have tremendous effects on accelerating the energy transition. I believe this prospect of how current trends, net-zero systems and near term measures can be tied together deserves more attention in the summary. References to show 100% RE are viable https://doi.org/10.1016/j.energy.2019.03.092 https://doi.org/10.1016/j.apenergy.2020.116273 https://doi.org/10.1016/j.energy.2008.04.003 , https://doi.org/10.1016/j.apenergy.2010.03.001 and https://doi.org/10.1016/j.apenergy.2010.03.006. DOI:10.1016/j.energy.2018.06.222 DOI: 10.1016/j.futures.2020.102644 https://doi.org/10.1007/s11027-019-9847-y https://doi.org/10.1016/j.egypro.2014.01.154 References advocating for socio-technial models https://doi.org/10.1016/j.techfore.2015.07.017 https://doi.org/10.1016/j.erss.2018.10.021 https://doi.org/10.1016/j.erss.2020.101559 https://doi.org/10.1016/j.erss.2018.12.010 Bergman, N, Haxeltine, A, Whitmarsh, L, Köhler, J, Schilperoord, M.P, & Rotmans, J. (2008). Modelling socio-technical transition patterns and pathways. Journal of Artificial Societies and Social Simulation: an inter-disciplinary journal for the exploration and understanding of social processes by means of computer simulation, 11(3), 1–32. Retrieved from http://hdl.handle.net/1765/19247	While these topics are interesting and important, space limits prevent us from addressing them in greater detail here.	Naud Loomans	Eindhoven University of Technology	Netherlands
28449	93	9	93	21	Very important paragraph. I think by now the number of net-zero or 100% RE studies have showed both are techno-economically feasable options. The current stagnation comes from policy makers and individuals unaware of which choices and policy measures to make right now under their local circumstances to achieve these high-level targets. A new area of modelling is comming up called socio-technical energy transuittoin models which adress these points. The report should advocate for further research in this domain, also connect multi-level models, integrating high-level system boundaries with local solutions and the other way around. And when doing so focus in analysis on identifying critical "Sensitive Intervention Points" which can have tremendous effects on accelerating the energy transition. I believe this prospect of how current trends, net-zero systems and near term measures can be tied together deserves more attention in the summary	While these topics are interesting and important, space limits prevent us from addressing them in greater detail here.	Naud Loomans	Eindhoven University of Technology	Netherlands

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
75641	93	9	93	21	This is a crucial paragraph, it would be highly appreciated if it would be elaborated upon. An incredibly large amount of recent research has shown that net-zero or 100% renewable energy both are techno-economically feasible options. Currently we are indeed observing a stagnation, an unnecessary slowing down of the process due to policy makers being unaware which options and policy strategies to take in their local context in order to reach these high-level targets. Fortunately, in the field of modelling the newly operated STEM (socio-technical energy transition models) will address this problem. It is important that this piece will advocate for the need to connect multi-level models – integration high-level system boundaries with local solutions and vice versa – and the need for further research on this topic. Hereby, please focus on the identification of critical Sensitive Intervention Points as these possess fantastical potential to accelerate the energy transition. Possible references for you to use are as follows: I.https://doi.org/10.1016/j.energy.2019.03.092 II.https://doi.org/10.1016/j.apenergy.2020.116273 III.https://doi.org/10.1016/j.energy.2008.04.003 , IV.https://doi.org/10.1016/j.apenergy.2010.03.001 V.https://doi.org/10.1016/j.apenergy.2010.03.006. VI.DOI:10.1016/j.energy.2018.06.222 VII.DOI: 10.1016/j.futures.2020.102644 VIII.https://doi.org/10.1007/s11027-019-9847-y IX.https://doi.org/10.1016/j.egypro.2014.01.154 X.https://doi.org/10.1016/j.techfore.2015.07.017 XI.https://doi.org/10.1016/j.erss.2018.10.021 XII.https://doi.org/10.1016/j.erss.2020.101559 XIII.https://doi.org/10.1016/j.erss.2018.12.010 XIV.Bergman, N, Haxeltine, A, Whitmarsh, L, Köhler, J, Schilperoord, M.P, & Rotmans, J. (2008). Modelling socio-technical transition patterns and pathways. Journal of	While these topics are interesting and important, space limits prevent us from addressing them in greater detail here.	Amira El-Feiaz	Technische Universiteit Eindhoven	Netherlands

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
85465	93	9	93	21	I would like to add that once you accept that the energy system should also take human behavior (either from end users or policy makers or others) into account you have to model a so called socio-technical system. So not just technical but socio-technical. It is becoming increasingly clear that agent-based modelling is the approach most suited for modelling such socio-technical systems. (I just received a grant to hire 35 PhDs to make an agent-based model for the Netherlands.) That agent-based modelling is mentioned nowhere in the chapter is a big omission and this is probably the best place to add it. Not only because it fits at the end of this paragraph but also because the next paragraph the behavioral domain is mentioned along with things like path-dependence and policy, all aspects that are easier to cover with agent-based models. Three important sources for this are: Hoekstra et al. 2017 https://doi.org/10.1155/2017/1967645 present a review of the field and why agent-based models are needed as an additional way to model realistic pathways towards low carbon energy systems. Hansen et al. 2018 https://doi.org/10.1016/j.erss.2018.10.021 reviews the agent-based modelling energy transition literature. Kraan et al. 2017 DOI 10.1007/978-3-319-47253-9_18 already showed that adding the agent-based perspective to IAMs creates insights not uncovered by IAMs. I could imagine adding the following senctences after line 21: "A novel development is modelling the energy transition using so called agent-based model that are able to capture the interaction between spatially and termporally explicit heterogeneous human agents and agents representing energy production and usage. This approach creates a 'digital twin' of an area in the computer and explores how the energy transition could 'play out' given the behaviors of agents and technological developments. This enables incorporating 'behaviors' of different stakeholders in combination with a detailed and evolving energy system (Hoekstra et	While these topics are interesting and important, space limits prevent us from addressing them in greater detail here.	Auke Hoekstra	Eindhoven University of Technology	Netherlands
84363	93	12	93	12	A description of the IAM is given in: Crassous, R. (2008). Thèse de doctorat de l'Institut des Sciences et Industries du Vivant et de l'Environnement. Modéliser le long terme dans un monde de second rang: application aux politiques climatiques.	Thank you for this suggestion. We have already introduced and described IAMs and other modeling types by this point in the chapter, so no additional references are necessary.	Vincent MAZAURIC	Schneider Electric	France
78699	93	18	93	21	this is partly true and also discussed in Hansen et al. (https://www.sciencedirect.com/science/article/pii/S0360544219304967), while highly detailed sector coupling studies with more than 100 technologies and for the sectors power, heat, transport, industry and desalination in hourly resolution also exist and shall be mentioned (see Bogdanov et al. https://www.sciencedirect.com/science/article/pii/S0306261920316639)	Thank you for your suggestions. Space constraints prevent us from expanding the references further.	Christian Breyer	LUT University	Finland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
82319	93	18	93	21	Many TIMES models include all sectors (both supply sectors and demand sectors), have a detailed description of each sector and also include process based emissions (hence capture all CO2 emissions). I have identified sector coupling in our scenario analysis using TIMES-Sweden, and I do believe that so have many of my IEA-ETSAP/TIMES colleagues. (We might need to be better to emphasize on this in our conclusions). Please acknowledge that there are modeling approaches, especially within the IEA-ETSAP modeling community, who include all sectors and are able to assess sector coupling. For example, see our analysis with TIMES-Sweden. In which one of the key message is: “Using existing biomass more efficiently, integrating biofuel production with the pulp and paper industry to use residues, and using waste heat for district heating are promising measures”: • Krook-Riekkola A., Sandberg E. (2018) Net-Zero CO2-Emission Pathways for Sweden by Cost-Efficient Use of Forestry Residues. In: Giannakidis G., Karlsson K., Labriet M., Gallachóir B. (eds) Limiting Global Warming to Well Below 2 °C: Energy System Modelling and Policy Development. Lecture Notes in Energy, vol 64. Springer, Cham. https://doi.org/10.1007/978-3-319-74424-7_8 Several similar TIMES studies are published in: • Giannakidis G., Karlsson K., Labriet M., Gallachóir B. (eds) (2018) Limiting Global Warming to Well Below 2 °C: Energy System Modelling and Policy Development. Lecture Notes in Energy, vol 64. Springer, Cham. https://doi.org/10.1007/978-3-319-74424-7 If you in this section mean sector coupling studies as in coupling the energy systems and the rest of the economy, we are several that has coupled detailed comprehensive energy system models (based on TIMES) with CGE models, see e.g.:	Thank you for your suggestions. Space constraints prevent us from expanding the references further.	Anna Krook-Riekkola	Luleå University of Technology	Sweden
64421	93	22	93	29	Consider also incorporating some discussion of the role of "black swan events", extreme innovators (e.g., Elon Musk), and unpredictable developments in technology, society, etc. For example, how well have past models predicted and incorporated the effects of the COVID pandemic, the housing market crash, and the rise of a global climate change movement spurred by the protests of a 15-year-old Swedish girl. In other words, unpredictable or rare events, sometimes tied to a single individual, can have extreme impacts on the system. This is started to be addressed on page 95, lines 25-30 - future technology, but could receive more attention in this chapter.	These are important topics and are indirectly referenced in this subsection ("rapid technological change" and "path dependence") but seem like better fits in another section.	Curt Bjurlin	Stantec Consulting	United States of America
2897	93	24	93	25	Some renewable and low-carbon fuels could benefit from the introduction of mininum share or quotas in specific end use sectors (for instance renewable hydrogen or advanced aviation fuels). This would contribute to reduce their costs and advance deployment.	Taken into account. This is covered in other sections (section 6.4)	Leonardo Barreto	Head of center "EU&International"	Austria
10669	93	24	93	24	Spurious "be"	Accepted.	Philippe Waldteufel	CNRS	France
43615	93	24	93	24	Replace "influence" with "influenced"	Accepted.	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
48147	93	31	93	31	"Carbon dioxide removal (CDR) technologies will likely be part of net-zero emission energy systems." Please clarify data from an actual DAC plant (Carbon Engineering) indicates that direct air capture increases air pollution and mining and hardly reduces carbon so is useless and should not be promoted as a solution. Jacobson, M.Z., The health and climate impacts of carbon capture and direct air capture, Energy and Environmental Sciences, 12, 3567-3574, doi:10.1039/C9EE02709B, 2019.	Rejected. Our conclusions here are based on synthesis of the literature reviewed and cited in the section.	Mark Jacobson	Stanford University	United States of America
12027	93	35	93	38	Add here that SRM may also be a potential limiting factor on the amount of CDR that may be required to meet 1.5-2, particularly in overshoot scenarios. Ref: SHEPHERD, J 2010 The 'napkin diagram' of multiple responses to climate change http://jgshepherd.com/wp-content/uploads/2011/01/Napkin-diagram.pdf	Noted. While this is an important discussion, it is beyond the scope of this chapter.	Paul Rouse	Carnegie Climate Governance Initiative (C2G) - The Carnegie Council for Ethics and International Affairs	United Kingdom (of Great Britain and Northern Ireland)
55847	93	37	93	39	The timeline for the statement is not defined. Is it by 2030 or another year?	Accepted. Text modified.	Government of United States of America	U.S. Department of State	United States of America
69705	93	38	93	38	The levels of renewable electricity generation and end-use electrification necessary to achieve net zero emissions will likely drive a reduction in primary energy use of 40% or more, while maintaining the same level of end-use services. 1) Currently about 38% of primary energy is devoted to electricity generation, with an average Carnot efficiency of less than 50%. Moving to renewable electricity generation, mostly hydropower, PV and wind power with no distinction between primary energy and electricity, will cut 10% of more in primary energy consumption (for the same electricity consumption level). Replacing fossil fuel use in buildings and ground transportation with electricity-driven heat pumps and electric traction chains will reduce fuel consumption in both sectors, and primary energy use, by a factor three or so (building retrofit for better insulation to be a useful complement to electrification). Reduction in the industry sector is probably less, and only the use of hydrogen and hydrogen-based fuels and feedstocks for chemicals, steel making, aviation and deep sea shipping, with relatively inefficient conversion processes, will avoid a near- collapse of primary energy needs. Hence the figures suggested in Grubler et alii (2018) seem reasonable.	Taken into account. These points are covered throughout sections 6.4 and 6.6	Cédric PHILIBERT	Institut Français des Relations Internationales	France
66725	93	40	93	44	These two sentences shall be reviewed. You first mention the role of BECCS and DAC, then you mention again their potential role. I find it a bit repetitive around the same concept	Noted. The first sentence is provided as the key message of this paragraph.	Chiodi Alessandro	E4SMA	Italy
69707	93	45	93	45	The need for dispatchable power in well-thought electricity grids with large amounts of variable renewables will be limited to "dark doldrums" (weeks with low solar and wind resources) and thus unlikely to be fit for BECCS.	Rejected. Our conclusions here are based on synthesis of the literature reviewed and cited in the section.	Cédric PHILIBERT	Institut Français des Relations Internationales	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
12029	94	1	95	16	Rather than use the 'institutional' in this section, it would be more appropriate to frame the section under the rubric of 'governance'. This (as per the Glossary definition) would be a more comprehensive framing which. It would encapsulate the institutional environment, but also how non-institutional actors interact with, influence and shape institutional behaviours in the context of transitions. The current framing (and diagram 6.3.3 implies linearity, which would be unfortunate) Reference example that sets out governance issues and gaps would include Mace, M.J., Fyson, C.L., Schaeffer, M., Hare, W.L. (2018). Governing large-scale carbon dioxide removal: are we ready? Carnegie Climate Geoengineering Governance Initiative (C2G2), November 2018, New York, US. https://www.c2g2.net/wp-content/uploads/C2G2-2018-CDR-Governance-1.pdf	Noted. This is in line with the blueprint followed throughout the chapter for internal consistency.	Paul Rouse	Carnegie Climate Governance Initiative (C2G) - The Carnegie Council for Ethics and International Affairs	United Kingdom (of Great Britain and Northern Ireland)
69709	94	1	94	2	Given a continuous need for e-kerosene for aviation and methanol for for chemical industries, biomass should be complemented with hydrogen from other renewables to deliver e-kerosene and e-methanol rather than being used to produce hydrogen.	Noted. The use of biomass to produce hydrogen could be one element. This is not defined as the only potential use.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
71737	94	2	94	3	The information on mitigation costs is misplaced here, as no other information on costs is provided here.	Accepted. Cross-reference to section 6.4 has been provided here.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
2899	94	7	94	7	The sentence is not clear. Why does DAC require less infrastructural coordination?	Accepted. Sentence modified.	Leonardo Barreto	Head of center "EU&International"	Austria
71739	94	7	94	9	It should be pointed out that DAC is not a CDR in this case.	Rejected. DAC could remain a CDR even with high energy consumption.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
69711	94	8	94	8	The sentence seems to suggest that the possibility of using CO2 captured from DAC in low-carbon methanol and other fuels would somehow compensate for the energy consumption of DAC - but it does not, as CO2 does not bring any energy potential to these fuel (it provides carbon that will allow to make higher energy density fuels, but it is fully oxydised and has no energy potential.)	Accepted. Sentence modified.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
33065	94	12	95	16	transition twords new clean and sustainable technologies creates many jobs. Therefore, there is a significant demand of CPD scheme and vocational training for technitions, professionals and students.	Taken into account	Yashar Hajimolana	University of Twente	Netherlands
47851	94	12	95	16	Section 6.6.3 should outline and discuss social equity and justice considerations for a related transition. Distribution of effects (equity) is mentioned in table 6.1, but not at all across the rest of Chpater 6. That is a significant short-coming.	Noted. We discuss distributional effects in section 6.7.6.2	Patrick Lamers	NREL	United States of America
55849	94	18	94	18	Figure 6.24 is somewhat confusing because the associated text states that there are three ways, but the graphic lists four. Understanding that the caption explains that the first three combine to influence the fourth, but the numbering system implies that these are four separate ways.	Can revise the figure/legend to make clear the four areas	Government of United States of America	U.S. Department of State	United States of America
63181	94	21	94	31	Linked to the concepts of embedded institutions, institutional environments, and transaction governance is the concept of institutional relationships between governments and energy sector actors, including consumers, power companies, and other actors. These relationships also affect the ability to transition to net zero systems, as governments can coordinate with or conflict with these groups regarding net zero goals and specific measure to achieve them. An example is Japan's shift away from government-utility-public cooperation on nuclear power as a solution to carbon emission reductions following the aFukushima disaster, (Sklarew, J. 2018. "Power Fluctuations: How Japan's Nuclear Infrastructure Priorities Influence Electric Utilities' Clout." Energy Research and Social Science, Volume 41. July: 158-167.)	Good idea, I can add a sentence and reference on the relationships between institutions, citing Sklarew's work	Jennifer Sklarew	George Mason University	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
15259	94	29	95	2	The sentence gives an example of some Chinese provinces planning to curtail and restrict renewable energy and rejecting the energy transition, which is incorrect and does not tally with the facts. China's relevant plans (on national economic and social development, energy) have always encouraged the development of renewable energy, and there are multiple objective reasons for the phenomenon of "wind abandonment" and "solar abandonment" in China (such as power regulation, grid transmission). It is suggested to delete the sentence “Examples include China, where some state planners seek to curtail renewable energy (Mori 2018)”. Supporting documents: National Development and Reform Commission of China, December 2016, "13th Five-Year Plan for Energy ". http://www.nea.gov.cn/135989417_14846217874961n.pdf	The Mori study is more independent and peer reviewed, it also postdates the 2016 plan. I believe Mori 2018 is a more reliable source	Government of China	China Meteorological Administration	China
47825	95	1	98	1	Regional aspects of net zero energy systems should discuss potential equity impacts.	Noted. equity and other fairness issues are discussed in section 6.7.6.2	Patrick Lamers	NREL	United States of America
5399	95	2	95	2	replace renewable by "wind and solar". There is not the same attitude against hydro or biomass.	Agreed, can implement this one	Michel SIMON	Retraité/ Pdt d'association	France
52257	95	4	95	16	The description of the US energy institutions is out of place, incomplete and should be removed.	We disagree, it's based on a peer reviewed study and clearly illustrates our point.	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
84365	95	4	95	16	Regarding the emergence of peer-to-peer energy exchange, blockchains, … the pyramidal architecture is clearly challenged. An other organization could be Russian doll-based. Anyhow, the issue of the physical parameters to share globally to act locally remains opened.	We can add some language to this effect describing the layering of infrastructures (the term here could be "nested hierarchies")	Vincent MAZAURIC	Schneider Electric	France
2901	95	13	95	15	Institutional changes are required to allow prosumers to participate in energy makets in a nondiscriminatory way. national legal and regulatory frameworks need to be adapted to allow consumers to engage in renewable energy communities, to participate in the activity of renewables self-consumption, or produce and share their energy with other prosumers	I would say that this is a policy descriptive statement	Leonardo Barreto	Head of center "EU&International"	Austria
17441	95	17	95	17	Energy powerty aspect is ignored in Chapter 6.6.4	Taken into Account: Wes specifically mention SDGs as a driver of net-zero energy system. Energy poverty is an important SDG.	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
82321	95	21	95	21	Please add district heating to the examples within the brackets. The reason for adding district heating is elaborated above. New sentence: “…. (e.g. electricity, district heating, hydrogen)”	Rejected. This is too specific.	Anna Krook-Riekkola	Luleå University of Technology	Sweden
2903	95	25	95	30	Societal factors are equally relevant to technology. Technological change cannot take place without substantial societal changes.	Taken into Account. Section 6.5.3 addresses societal factors, and we mention societal preferences and the influence of SDGs here in this section.	Leonardo Barreto	Head of center "EU&International"	Austria
71741	95	25	97	20	The paragraph on societal preferences is the only one with sufficient evidence from the literature. All other paragraphs need to be linked to the literature.	Taken into Account. We have frequently linked the paragraphs to other parts of the chapter, where issues are addressed in more detail.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
52259	95	26	95	26	Sentence makes no sense.	Accepted. Sentence has been improved	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
63667	95	31	95	38	In several countries, forests are an indigenous energy resource.	Taken into Account. We've clarified land can be used for bioenergy. But note that this paragraph is about energy resources, so forests are only an energy resource if they are used for bioenergy.	Government of Canada	Environment and Climate Change Canada	Canada
82323	95	41	95	43	Like mentioned above. Replacing district heating with heat-pumps might make it more difficult to reach net-zero emissions. I suggest to rewrite the sentence in line with any of the following: In net-zero systems, however, heating may be increasingly served by electricity through the use of heat pumps (Section 6.6.4), when district heating is not available, limiting the distinction between fuel types emerging from differences in climate. OR In net-zero systems, however, heating may be increasingly served by electricity through the use of heat pumps (Section 6.6.4), either replacing fossil fuels in the buildings or in the district heating networks, limiting the distinction between fuel types emerging from differences in climate.	Taken into Account. We have removed the specific reference to heat pumps and instead noted simply that we will see more electrification.	Anna Krook-Riekkola	Luleå University of Technology	Sweden
51431	95	42	95	43	through the use of heat pumps (Section 6.6.4), particularly for well-insulated new buildings, limiting the distinction between	Rejected. Too detailed for this level of synthesis.	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
51433	95	42	95	43	fuel types emerging from differences in climate; though in some regions hydrogen or district heating may be used.	Rejected. Too detailed for this level of synthesis.	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
17535	96	2	96	2	DSOs?	Noted. We don't undersatnd this comment.	Alaa Al Khourdajie	IPCC	United Kingdom (of Great Britain and Northern Ireland)
2905	96	5	96	8	Regional integration requires strong and effective regional governance systems that faciltate cross-border interconnections and regional markets	Taken into Account. This is addressed at length in section 6.4 and to some degree in earlier portions of Section 6.6, as well as the regional integration box.	Leonardo Barreto	Head of center "EU&International"	Austria
51435	96	7	96	8	but will have their net zero energy systems somewhat dependent on those resources. {Is this what is meant?}	Taken into Account. Sentence is clearer now.	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
66729	96	9	96	9	I find a bit unclear the definition of countries in Figure 6.25 for category 'OECD + EU'. Is it not true that all EU countries are part of OECD? If so, I would mention this category just as 'OECD', as there's no ambiguity	Taken into Account. We are revising the regional representations to be consistent with the IPCC guidance	Chiodi Alessandro	E4SMA	Italy

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
74751	96	9	96	9	show legend	Noted. We don't understand this comment. The legends are shown in the figure.	Debadutta Mohanty	CSIR - Central Institute of Mining and Fuel Research, Dhanbad	India
55851	96	10	96	15	The caption should be extended to provide more information about what the reader is seeing in the graphic.	Taken into Acount. We have tried to clarify the caption.	Government of United States of America	U.S. Department of State	United States of America
17443	96	16	97	6	Only very rich countries are considered in "Societal Preferences" paragraph. What about majority of the World population?	Taken into Account. The paragraph has been changed to make more general points.	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
66733	96	16	97	6	You state 'Preferences for non-renewable energy differs across regions and groups', however you don't provide any example as done for the renewables case. I think an example may be worth to be added	Taken into Account. The paragraph has been changed to be less detailed.	Chiodi Alessandro	E4SMA	Italy
63183	96	17	96	18	While it may be true that "the public generally prefers futures based largely on renewable energy," many communities also express NIMBYism, or "not in my backyard" preferences regarding siting of renewables.	Noted. This is too much detail for the point of the paragraph, which is simply that preferences are different across countries, groups, and technologies.	Jennifer Sklarew	George Mason University	United States of America
66731	97	2	97	2	Formatting of references to be reviewed	Accepted	Chiodi Alessandro	E4SMA	Italy
17445	97	12	97	12	Energy security aspect of non-dispatchable wind and solar are not mentioned although they result in much more unstable electricity system than hydro (and bioenergy).	Taken into Account. Text has been revised and the issue has been raised.	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
55853	97	12	97	16	The reference to greater regional integration would conflict with the goal increasing energy security, particularly if the concern is related to energy imports.	Noted. Agreed. This is noted in the text.	Government of United States of America	U.S. Department of State	United States of America
2909	97	17	97	20	The capacity of countries (especially developing countries) to adsorb technology from other countries also plays an important role. Building national or regional systems of innovation that enable domestic innovation and increase absorption capacity to acquire technology from abroad requires long-term efforts on policy, financial support and coordination of different actors (business, academia, governments, civil society etc.) and must be accompanied by international efforts to develop a supportive environment for technology transfer.	Taken into Account. The point about capacity has been added.	Leonardo Barreto	Head of center "EU&International"	Austria
52261	97	19	97	20	Sentence is vague and too general.	Taken into account. The sentence has been improved, and it refers back to 6.3.3.	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
78705	97	22	98	21	please enlarge the text box also beyond hydrogen only, as there are several hydrogen-based fuels which are substantially more easy to transport and thus also generate positive impact, such as methane, Fischer-Tropsch fuels, methanol and ammonia. This has been studied in much detail and quanified for a global synthetic fuel/chemicals trade in a recent report commissioned by the German Energy Agency (https://www.powerfuels.org/fileadmin/powerfuels.org/Dokumente/Global_Alliance_Powerfuels_Study_Powerfuels_in_a_Renewable_Energy_World.pdf), which structural new findings. Such findings are completely missing in the text box, but of highest relevance for regionla integration.	Taken into Account. We discuss hydrogen transportation in another box on the hydrogen economy and in Section 6.4. And we should note that this box does not just focus on hydrogen. It also covers electricity and biomass.	Christian Breyer	LUT University	Finland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
64423	97	30	97	46	More attention needs to be given to the challenges of electricity system integration. The benefits are well-described, but the impediments need to be identified and addressed to focus attention on potential solutions.	Taken into account. We have a statement on integration for each of the three categories.	Curt Bjurlin	Stantec Consulting	United States of America
78703	97	30	98	2	it will be valuable to work in the fundamental findings of Breyer et al. (https://www.iaee.org/eeep/article/305) summarising a broader body of literature on electricity system integration, as a major regional integration has been found to be consistently beneficial across the world (e.g. Europe, North America, MENA, Southeast Asia, etc.), but an integration beyond such large regions to even larger super regions (e.g. entire East Asia, entire Americas, global power super grid) has found to generate no relevant extra benefit. Breyer et al. have been the only team carrying out such an analysis in full hourly resolution to the knowledge of the reviewer	Noted. We discuss electricity system integration in detail in Section 6.4.	Christian Breyer	LUT University	Finland
10671	97	33	97	36	While the statement adresses renewable sources, capacity and energy, the reference you quote (Newbery et al) gives very little attention to renewable sources.	Taken into account. The reference has been removed as part of tightening the text.	Philippe Waldteufel	CNRS	France
17447	97	34	98	2	Societal aspect of new transmission electricity lines is not mentioned although they present an importand drawback of electricity system integration.	Accepted.	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
77247	97	34	97	36	The same example, reported in page 63, lines 39-46, cites different numbers: 150 GW and €180bn instead of 160 GW and € 150bn. The two references should be checked and made coherent.	Taken into Account. The citation has been rmeoved as the text has been tightened.	Giacomo Grasso	ENEA	Italy
78701	97	39	97	39	The reference used in this line mixes the first and last name	Noted, This should be corrected	Christian Breyer	LUT University	Finland
55855	98	3	98	3	Recommend adding a sentence to start this paragraph saying: "Hydrogen can be used to decarbonize regions in which it is produced, and can also be transported long distances to facilitate decarbonization of sectors distant from sources of low-cost supply. Methods of long-distance, high-volume hydrogen transport could include liquid storage, chemical carriers, and gaseous delivery via pipelines."	Accepted	Government of United States of America	U.S. Department of State	United States of America
55857	98	3	98	8	Include other "net zero" or low emissions chemicals (e.g., ammonia).	Taken into Account. The paragraph has been substantially revised.	Government of United States of America	U.S. Department of State	United States of America
70223	98	23	99	8	It is mentioned in App. C that IAMs currently do not (sufficiently) take LCA coefficients into consideration. However, I think this needs to be mentioned more prominently in Chapter 6, section 6.7.1. as well. See e.g. Pehl et al. (https://www.nature.com/articles/s41560-017-0032-9).	Noted. This chapter puts focus on "Energy System Transitions", rather than analysis tools. Furthermore, the suggested literature concludes " Fully considering life-cycle greenhouse gas emissions has only modest effects on the scale and structure of power production in cost-optimal mitigation scenarios."	Paul Wolfram	Yale University	United States of America
55859	98	25	98	26	Elevate this important point to the Executive Summary, Technical Summary, and SPM.	Note. There is a similar message in TS and SPM.	Government of United States of America	U.S. Department of State	United States of America
55861	98	25	98	38	What is the timescale for these baselines? Is it to 2050 or another year?	Accepted. Added "toward 2050" to the sentence.	Government of United States of America	U.S. Department of State	United States of America
2501	98	28	98	28	Should "CO2 emissions fossil fuel" be "CO2 emissions FROM fossil fuel"?	Accepted. Added "from" to the sentence.	Taoyuan Wei	CICERO Center for International Climate Research	Norway
71743	98	28	98	28	Global CO2 emissions FROM fossil fuel combustion	Accepted. Added "from" to the sentence.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
52263	98	37	98	38	Countries in Asia, the Middle East, and Africa are catching up in terms of development; the sentence makes it sound like these countries are responsible for CO2 emissions and ignores the current and historical emissions of other countries.	Noted. This statement is about a future baseline scenario, not about historical responsibility of CO2 emissions.	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
55863	98	39	98	40	The sentence repeats limiting warming to 1.5°C twice.	Accepted. Removed duplicate part.	Government of United States of America	U.S. Department of State	United States of America
10967	98	40	98	40	delete "to limit warming to 1.5℃"	Accepted. Removed duplication.	Dong-Woon NOH	Korea Energy Economics Institute	Republic of Korea
16391	98	40	98	40	delete "to limit warming to 1.5℃"	Accepted. Removed duplication.	Government of Republic of Korea	Korea Meteorological Administration (KMA)	Republic of Korea
28637	98	40	98	40	"limit warming to 1.5C" is repeated unecessarily at end of sentence	Accepted. Removed duplication.	Tim Dixon	IEAGHG	United Kingdom (of Great Britain and Northern Ireland)
71745	98	40	98	40	1.3–2.2%a > the "a" is too much	Noted. The corresponding part has been rewritten.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
2703	99	2	99	5	Emissions from CO2 is a strange title	Accepted. The title has been removed.	Jan Wohland	ETH Zurich	Switzerland
84367	99	6	99	7	Please specify the regions in the caption.	Accepted. Added a legend of the region to the figure.	Vincent MAZAURIC	Schneider Electric	France
51437	99	8			Identify in caption for Fig 6.27 the regions shown	Accepted. Added a legend of the region to the figure.	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
55865	99	8	99	8	The Figure 6.27 caption needs to explain the graphics, the acronyms, and what the reader is seeing.	Accepted. Added a legend of the region to the figure.	Government of United States of America	U.S. Department of State	United States of America
66735	100	2	100	4	Sentence to be rephrased/revised	Noted. The paragraph in which the sentence appears has been rewritten.	Chiodi Alessandro	E4SMA	Italy
71747	100	3	98	3	after the energy system becomes reaches net-zero > the "becomes" should be removed	Accepted. "becomes" is removed.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
84371	100	9	100	11	Regarding the issue of self-consumption dedicated to the control of the flexible, diluted and variable power system itself, the net zero should be harder to reach.	Noted. Feasibility of the net zero is discussed in another part of the chapter.	Vincent MAZAURIC	Schneider Electric	France
7895	100	15	100	17	The energy system includes sectors that are relatively easy to electrify and are expected to reduce emissions early, such as residential heating -- would suggest that the passenger vehicle sector has greater global applicability than this statement. Also - with a UK perspective - it is far from 'relatively easy' to electricty the poor housing stock in the UK. Significant fabric improvements will be required in parallel.	Noted. Promoting the use of EVs in passenger cars without making the electric power sector low-carbon will not contribute to reducing emissions from the transportation sector. We have already pointed out that improving energy efficiency is important not limited to the building sector.	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
71749	100	24	100	25	The text mentions "substantial bioenergy potential" and "bioenergy trade". Discuss whether this is sustainable bioenergy	Noted. The sustainability of bioenergy is addressed in other chapters, such as Chapter 7 and Chapter 17.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
7897	100	27	100	34	This paragraph would benefit from some greater clarity - as is not entirely clear why the inverse relationship is there.	Accepted. This paragraph is revised.	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
55867	100	27	100	34	The content of this paragraph could be clarified to better explain the inverse relationship that is described. It seems counterintuitive that a delay in climate action will accelerate the feasible timing for reaching net-zero energy systems.	Accepted. This paragraph is revised.	Government of United States of America	U.S. Department of State	United States of America
2503	100	37	100	37	should "understanding can, however, can provide" be "understanding can, however, provide"?	Accepted. "can" is deleted.	Taoyuan Wei	CICERO Center for International Climate Research	Norway
71751	100	37	100	37	can, however, can > second "can" is too much	Accepted. "can" is deleted.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
2705	100	42	100	44	Hanna et al. (2021) show that even an emergency-like CDR response to insufficient mitigation requires to start investments early to initiate technological learning and scale effects. Hanna, R., Abdulla, A., Xu, Y., Victor, D.G., 2021. Emergency deployment of direct air capture as a response to the climate crisis. Nat Commun 12, 368. https://doi.org/10.1038/s41467-020-20437-0	Noted. We deal with CDR option in 6.7.1.4 "Technology options to offset residual emissions"	Jan Wohland	ETH Zurich	Switzerland
4837	101	7	101	7	"Section 6.7.1.3 Energy transition strategies": Models running scenarios for electric power systems, bringing all technologies on line should have the proper fine time resolution (hourly, quarter-hourly, minutes) to approach the almost real-time characteristics of electric current (in Watt = Joule/second). Juxtaposing yearly batches of generated and consumed electric energy (in TWh units) in the models hides essential momentary conflicts between various technologies (in particular between variable renewable power and nuclear power. This leads to significantly flawed statements about energy portfolios.	Noted. This section has been substantially revised and reorganized.	Aviel Verbruggen	University of Antwerp	Belgium
24983	101	7	106	27	New research seeks to connect high level net-zero or low-carbon energy models and concrete strategies and policy measures towards this goal. Sensitive Intervention Points (SIPs) have become a key point of focus in this field, thus emphasising feedback loops, tipping points and non-linear behaviour (Farmer et al. 2019). SIPs can be technological or economic, but also social and institutional. This holistic perspective is useful for analysing transition pathways and specific policies. Given the importance of uniting visions and concrete actions, it would be valuable for this section of Chapter 6 to discuss this topic. A useful reference may be found with this doi: 10.1126/science.aaw7287	Noted. This section has been substantially revised and reorganized. While the SIP primarily discusses socio-economic transformation, this section focusses on transitions in the energy system.	Emil Beemer	Dutch Research Institute For Transitions, Erasmus University Rotterdam	Netherlands

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
28443	101	7	106	27	Current state-of-the art research is focussing on bridging the gap between high level net-zero or low-carbon energy models and concrete strategies and policy measures towards this goal. One of the main points of focus are sensitive intervention points (SIPs) (Farmer et al. 2019). In other words, investigate feedback loops, tipping points and non-linear behaviour. These SIPS could be techno-economic, such as cost reductions in batteries triggering potential in cars, trucks, grid balancing and other usages, but also social or institutional. For example the Paris climate agreement has been institutional in improved climate targets, public spending on research and development and the general acceptance of climate change. Such events could either trigger acceleration or deceleration, and are vital for assesing policies and transition pathways. This section on near term strategies is the place in the report to adress these topics. DOI: 10.1126/science.aaw7287	Noted. This section has been substantially revised and reorganized.While the SIP primarily discusses socio-economic transformation, this section focusses on transitions in the energy system.	Naud Loomans	Eindhoven University of Technology	Netherlands
63669	101	7	106	26	There is very little in the energy transition strategies section on solutions for thermal energy, except to say that most space heating will be electrified. Most northern countries (at least in the EU) with high space heating demand have built out district heating infrastucture, fuelled largely by waste heat and biomass, as a key component of decarbonization strategies.	Noted. This section has been substantially revised and reorganized. Mitigation strategies in building sector are discussed in detail in Chapter 8 and 9.	Government of Canada	Environment and Climate Change Canada	Canada
74211	101	7	106	26	This section relies to heavily on the editorial viewpoint that wind and solar will be the primary drivers in driving mitigation strtategies. It fails to account for other carbon free generation including nuclear, hydro and geothermal among others.	Noted. This section has been substantially revised and reorganized.	Jeffrey Merrifield	Pillsbury Law Firm	United States of America
64259	101	8	101	16	As it has been said regarding p SPM-35, energy efficiency is by far the most important means to meet the 2°C target – this was very clearly state in the previous IPCC 2014 SPM and in particular in its Figure SPM.9 – see excerpt hereafter. Excerpt out of previous “IPCC-5 (2014) : significant changes in investment flows e.g. from 2010 to 2029, in billions of US dollars per year” The substantial emissions reductions needed to meet the 2°C target require significant changes in investment flows – for example from 2010 to 2029 in billions of US dollars per year (rounded figures, max in OECD countries): • energy efficiency + 330 • renewables + 90 • nuclear + 40 • fossil power plants with CCS + 30 • fossil power plants without CCS - 60 • fossil fuel extraction - 90 (Total electricity generation + 100) Source: IPCC, 2014: “Summary for Policymakers (SPM). In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change” - Figure SPM.9 - [Edenhofer, O., …..and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. - https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_summary-for-policymakers.pdf	Noted. While it is agreed that improving energy efficiency is important, and this is included in the section, it should also be noted that improving energy efficiency alone will not achieve net zero.	Georges VAN GOETHEM	Royal Academy of Overseas Sciences (ARSOM - KAOW)	Belgium
55869	101	9	101	11	Is it correct to classify nuclear and CCS as renewable energy sources?	Accepted. This paragraph has been substantially revised.	Government of United States of America	U.S. Department of State	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
43003	101	10	101	12	There is some inconsistency of how different technologies are considered throughout the Chapter. In these lines, hydropower could be considered as many projects have similar lifetime carbon footprints to the identified technologies. Similliary nuclear power is rightly identified here as a low emission energy source, but elsewhere in the chapter it is inferred to be an overall negative technology. It can be difficult to reconcile the consensus of the IPCC when there are different undertones relating to the same technology. I believe this author of this section takes a more balanced approach to the various available technology options.	Noted. This section has been substantially revised and reorganized in a balanced manner.	Kurt Kornelsen	Ontario Power Generation	Canada
30733	101	21	101	23	nuclear power already serves as an important role providing low carbon energy. Therefore, "nuclear" should be moved to the previous sentence as below. Renewable energy, including solar, wind hydropowar, bioenergy, [delete: and] geothermal, [add:: and nuclear】, will have an important role...	Noted. This paragraph has been substantially revised.	Government of Japan	Climate Change Division - Ministry of Foreign Affairs	Japan
80645	101	21	102	4	Bioenergy should not be included as renewable energy. In fact, bioenergy is not carbon neutral in the near-term—with a carbon deficit for many years, generally several decades to a century—that is crucial for mitigating emissions and avoiding hitting the 1.5°C mark. Danielle Venton, Core Concept: Can bioenergy with carbon capture and storage make an impact?, PNAS (2016); Leturcq, P. (2020) GHG Displacement Factors of Harvested Wood Products: the Myth of Substitution, Nature Scientific Reports 10:1–9; Mary S. Booth, Not carbon neutral: Assessing the net emissions impact of residues burned for bioenergy, Environ. Res. Lett. 13 (21 February 2018); Sterman J. D., et al. (2018) Does replacing coal with wood lower CO2 emissions? Dynamic lifecycle analysis of wood bioenergy, Envtl. Research Letters 13(015007):1–10, 1 ("We simulate substitution of wood for coal in power generation, estimating the parameters governing NPP and other fluxes using data for forests in the eastern US and using published estimates for supply chain emissions. Because combustion and processing efficiencies for wood are less than coal, the immediate impact of substituting wood for coal is an increase in atmospheric CO2 relative to coal. The payback time for this carbon debt ranges from 44–104 years after clear-cut, depending on forest type—assuming the land remains forest. Surprisingly, replanting hardwood forests with fast-growing pine plantations raises the CO2 impact of wood because the equilibrium carbon density of plantations is lower than natural forests. Further, projected growth in wood harvest for bioenergy would increase atmospheric CO2 for at least a century because new carbon debt continuously exceeds NPP. Assuming biofuels are carbon neutral may worsen irreversible impacts of climate change before benefits accrue. Instead, explicit dynamic models should be used to assess the climate impacts of biofuels."). Furthermore, even if BECCS were net zero or negative in the relevant next couple of decades, which it is not, large-scale biodiversity development requires vast land-use changes, which may have significant implications for food security and biodiversity. National Academies of Sciences, Engineering, and Medicine, Negative Emissions	Rejected. Bioenergy is classified as a type of renewable energy, and SRREN defines renewable energy as follows; Renewable energy (RE) is any form of energy from solar, geophysical or biological sources that is replenished by natural processes at a rate that equals or exceeds its rate of use. The sustainability of bioenergy is addressed in other chapters, such as Chapter 7 and Chapter 17.	Durwood Zaelke	Institute for Governance & Sustainable Development	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
80789	101	21	102	4	Bioenergy should not be included as renewable energy. In fact, bioenergy is not carbon neutral in the near-term—with a carbon deficit for many years, generally several decades to a century—that is crucial for mitigating emissions and avoiding hitting the 1.5°C mark. Danielle Venton, Core Concept: Can bioenergy with carbon capture and storage make an impact?, PNAS (2016); Leturcq, P. (2020) GHG Displacement Factors of Harvested Wood Products: the Myth of Substitution, Nature Scientific Reports 10:1–9; Mary S. Booth, Not carbon neutral: Assessing the net emissions impact of residues burned for bioenergy, Environ. Res. Lett. 13 (21 February 2018); Sterman J. D., et al. (2018) Does replacing coal with wood lower CO2 emissions? Dynamic lifecycle analysis of wood bioenergy, Envtl. Research Letters 13(015007):1–10, 1 ("We simulate substitution of wood for coal in power generation, estimating the parameters governing NPP and other fluxes using data for forests in the eastern US and using published estimates for supply chain emissions. Because combustion and processing efficiencies for wood are less than coal, the immediate impact of substituting wood for coal is an increase in atmospheric CO2 relative to coal. The payback time for this carbon debt ranges from 44–104 years after clear-cut, depending on forest type—assuming the land remains forest. Surprisingly, replanting hardwood forests with fast-growing pine plantations raises the CO2 impact of wood because the equilibrium carbon density of plantations is lower than natural forests. Further, projected growth in wood harvest for bioenergy would increase atmospheric CO2 for at least a century because new carbon debt continuously exceeds NPP. Assuming biofuels are carbon neutral may worsen irreversible impacts of climate change before benefits accrue. Instead, explicit dynamic models should be used to assess the climate impacts of biofuels."). Furthermore, even if BECCS were net zero or negative in the relevant next couple of decades, which it is not, large-scale biodiversity development requires vast land-use changes, which may have significant implications for food security and biodiversity. National Academies of Sciences, Engineering, and Medicine, Negative Emissions	Rejected. Bioenergy is classified as a type of renewable energy, and SRREN defines renewable energy as follows; Renewable energy (RE) is any form of energy from solar, geophysical or biological sources that is replenished by natural processes at a rate that equals or exceeds its rate of use. The sustainability of bioenergy is addressed in other chapters, such as Chapter 7 and Chapter 17.	Gabrielle Dreyfus	Institute for Governance & Sustainable Development	United States of America
12211	101	22	101	23	We believe that there needs to be an emphasis here regarding the stabilizing role of nuclear and gas with CCUS as the backbone of the future energy grids. Nuclear power is forecasted to have a significant role in the energy transition as the UNECE report on "The Role of Nuclear Energy in Sustainable Development" which presents multiple scenarios which envisage a growing role for nuclear power: The IEA two-degree scenario - By 2050, it projected nuclear energy to be one of the largest low carbon electricity sources, accounting for up to 17 per cent of global electricity demand (2015 edition). The Deep Decarbonization Pathways Project (DDPP) - nuclear energy grows by 1053 gigawatts to produce 8665 terawatt-hours per year and supply 21 per cent of electricity by 2050. To name just two of the projections. Saying that nuclear might also play an important role might be seen as an understatement.	Accepted. This paragraph has been substantially revised.	Lavinia Rizea	SN Nuclearelectrica SA	Romania
2707	101	27	102	1	Why "and". There is no good reason why all of them need to grow. Fossil with CCS is not an option for carbon neutral power systems due to the residual emission that would require additional CDR. I would see the point of peaking fossil with CCS but it is not clear that this what is meant here.	Noted. This paragraph has been substantially revised.	Jan Wohland	ETH Zurich	Switzerland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
51439	101	27			Also, non-fossil low-carbon energy sources, {substitute 'also' for 'alternatively'}	Noted. This paragraph has been substantially revised.	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
77249	101	27			The statement incipits with "Alternatively", but the need for an increase of low-carbon energy sources is not alternative to that of reduction of fossil ones. Suggested to replace with "Additionally" or similar.	Noted. This paragraph has been substantially revised.	Giacomo Grasso	ENEA	Italy
18263	102	1	102	4	(Section 6.7.1.3) "Bioenergy may be used because it is a versatile substitute for fossil fuels where electrification is not possible.... Hydrogen can also be an attractive option, but the carbon footprint of hydrogen, depends on the primary energy sources and the process used for its production". As with hydrogen, the carbon footprint of bioenergy is entirely dependent on the primary source and the production process. Suggest making this clear, or the implication is that this is true for hydrogen but not for bioenergy, which is potentially misleading.	Noted. This paragraph has been substantially revised.	Government of United Kingdom (of Great Britain and Northern Ireland)	Department for Business, Energy & Industrial Strategy	United Kingdom (of Great Britain and Northern Ireland)
63671	102	1	202	2	Most northern countries (at least in the EU) with high space heating demand have built out district heating infrastucture, fuelled largely by waste heat and biomass, as a key component of decarbonization strategies, despite the fact that space heating can easily be electrified. It has not been demonstrated that electrification should be done everywhere possible and that bioenergy should be used where it is not possible.	Noted. This section has been substantially revised and reorganized. Mitigation strategies in building sector are discussed in detail in Chapter 8 and 9.	Government of Canada	Environment and Climate Change Canada	Canada
2505	102	3	102	4	The statement for hydrogen seems valid for any renewables like solar and wind. Why do you emphasize hydrogen alone? It is not sufficient just because its large share of low carbon energy sources in the future, I think.	Rejected. Hydrogen is an energy carrier, not primary energy source, so its carbon footprint depends on the primary energy sources and the process used for its production. On the other hand, renewables are primary energy sources. Each has different characteristics in terms of carbon footpring.	Taoyuan Wei	CICERO Center for International Climate Research	Norway
5401	102	3	102	7	The whole sentence has to be deleted since hydrogen is not a source of energy, but only a vector for storage.	Noted. It is true that hydrogen is not a source of energy, but it can also contribute to cutting CO2 emissions.	Michel SIMON	Retraité/ Pdt d'association	France
51441	102	7			sources (Figure 6.29). But green hydrogen could be cost-competitive by 2030.	Noted. Green hydrogen could be cost-competitive by 2030, but its share is limited compared to solar and wind according to the database.	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
51443	102	7			see https://www.irena.org/publications/2020/Dec/Green-hydrogen-cost-reduction	Noted. Green hydrogen could be cost-competitive by 2030, but its share is limited compared to solar and wind according to the database.	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
18265	102	8	102	12	(Section 6.7.1.3) The figures here are confusing (eg five times is written quadruple). Suggest rewording.	Accepted. The sentence is reworded.	Government of United Kingdom (of Great Britain and Northern Ireland)	Department for Business, Energy & Industrial Strategy	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
2709	102	13	102	15	Caption says primary energy, title says electricity supply. Which one is correct? How is primary energy computed for wind and solar? Fundamentally unclear what the differently colored boxpltos mean here. There are no x axes labels.	Accepted. The title of the figure is corrected. Label and legend are added to the figure.	Jan Wohland	ETH Zurich	Switzerland
7899	102	13	100	13	Figure 6.29 needs a colour legend	Accepted. Label and legend are added to the figure.	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
64141	102	13	102	13	X-axis units (i.e., years) are missing in Figure 6.29, without that it is difficult to understand.	Accepted. Label and legend are added to the figure.	Ghulam Rasul Athar	Pakistan Atomic Energy Commission	Pakistan
66737	102	13	102	13	The titles of Figure 6.29 are cut and on the x-axis no values and legends are reported	Accepted. Label and legend are added to the figure.	Chiodi Alessandro	E4SMA	Italy
71753	102	13	102	13	Horizontal axes are missing in Fig. 29. No explanation of grey and green colours	Accepted. Label and legend are added to the figure.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
76133	102	16	104	8	The approach and methodology of results presentation in Box 6.9 is not appropriate. It is claimed that "The illustrative pathways presented in this box demonstrate four distinct strategies for energy system transformations.." For the strategies to be compared they have to have identical or at least similar starting positions. Yet, four strategies presented are for four different regions with completely different starting situation. Also, for all regions nuclear yield is pressumed small on equal to zero, even in the regions with strong nuclear new build like Asia or UAE.	Noted.The box has been modified. Each pathway is in a different region, so it is not surprising that the situation at the start is different.	Krešimir Trontl	University of Zagreb, Faculty of Electrical Engineering and Computing	Croatia
84495	102	16	104	8	Box 6.9 includes useful context that also provides a regional perspective of energy system transitions. The five high level region classification of IPCC is slightly modified that may be clarified or harmonized.	Noted.The box has been modified.	Siir KILKIS	The Scientific and Technological Research Council of Turkey	Turkey
27737	102		102		Figure 6.29 is not clear, e.g. the horizontal axis does not have values. Is this years? The legend is also missing.	Accepted. Label and legend are added to the figure.	Eleni Kaditi	Organization of the Petroleum Exporting Countries, OPEC	Austria
77251	102				Both plots in figure 29 miss labels on the x axis.	Accepted. Label and legend are added to the figure.	Giacomo Grasso	ENEA	Italy
2711	103	1	103	4	How can this be a net zero economy in 2038 given 25% (or so) primary energy from fossils without CCS? If this is all compensated using loads of CDR, this should be stated explicitly somewhere.	Noted. As noted in the description of the figure, Latin America & Caribbean heavily rely on carbon sequestration and AFOLU, which do not appear in the figure.	Jan Wohland	ETH Zurich	Switzerland
64143	103	1	103	1	Explanation are needed on Energy System Transitions shown in Box 6.9, particularly for those regions which have atypical scenarios. i.e., in Figure 1 of Box 6.9; Illustrative Pathway 1.5-Sup: Latin America & Caribbean(in a 1.5°C scenario net-zero economy, 2038, net zero energy system 2056), there are slight dips in Primary Energy Supply and Final Energy Consumption around year 2038. However, there is a large dip for Final Energy Consumption per capita around 2038. Therefore, it is needed to explain assumptions on population growth and efficiency improvement, etc.Data in Table 1 of in the Box is not sufficient.	Noted. This is not an ensemble mean of the scenarios, but a pickup of a single scenario, so sometimes the data fluctuate.	Ghulam Rasul Athar	Pakistan Atomic Energy Commission	Pakistan

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
66739	103	1	103	1	Final Energy per capita declines up to 2035 and then steaply increase. Which is the reason of this behaviour?	Noted. This is not an ensemble mean of the scenarios, but a pickup of a single scenario, so sometimes the data fluctuate.	Chiodi Alessandro	E4SMA	Italy
12215	104	1	104	7	We don not agree with the projected scenario for Europe. The percentage of nuclear power in the future energy mix is estimated to be 15% and above: the EC Communication “A Clean Planet for All”, November 2018, said that “by 2050, more than 80% of electricity will be coming from renewable energy sources (increasingly located off-shore). Together with a nuclear power share of ca. 15%, this will be the backbone of a carbon-free European power system”, appreciating that “these transitions are similar to global pathways analysed in the IPCC report”.	Noted. Scenario does not necessarily correspond to stated policy.	Lavinia Rizea	SN Nuclearelectrica SA	Romania
78707	104	13	104	21	this is consistently found in the community of highly renewables, but not a single reseaerch of that group is cited, which does not provide a full overivew on the body of literature. This misbalance shall be corrected. Respective overview can be found in Hansen et al. (https://www.sciencedirect.com/science/article/pii/S0360544219304967), is provided by Jacobson et al. (https://www.sciencedirect.com/science/article/pii/S2590332219302258), by Teske (https://www.springer.com/gp/book/9783030058425), and also Ram et al. (http://energywatchgroup.org/wp-content/uploads/EWG_LUT_100RE_All_Sectors_Global_Report_2019.pdf).	Noted. Providing a full overivew on the body of literature is not the main purpose of the sentence.	Christian Breyer	LUT University	Finland
10969	104	17	104	17	delete "than" in "CO2 emission than in other sectors"	Accepted	Dong-Woon NOH	Korea Energy Economics Institute	Republic of Korea
16393	104	17	104	17	delete "than" in "CO2 emission than in other sectors"	Accepted	Government of Republic of Korea	Korea Meteorological Administration (KMA)	Republic of Korea
73997	104	24	104	24	Reference for electrification rate is needed.	Accepted. Reference inserted	Heleno Miguel	Lawrence Berkeley National Laboratory	United States of America
77253	104				In figure 4, the illustrated trend of nuclear generation does not reflect the declared policies in the region.	Noted. Scenario does not necessarily correspond to stated policy.	Giacomo Grasso	ENEA	Italy
77255	104				In table 1, it could be worth to change title of column 5 in the first row from "Variable renewable capacity" to "Low carbon energy generation".	Rejected. "Low carbon energy generation" does not necessarily mean "Variable renewable capacity". In this context, "Variable renewable capacity" is the correct title.	Giacomo Grasso	ENEA	Italy
66741	105	2	105	2	Typo: detei rminant	Accepted. Typo fixed (106 page line 2)	Chiodi Alessandro	E4SMA	Italy
55871	105	10	105	10	Recommend replacing "countries" with "regions".	Accepted. Replaced "countries" with "regions"	Government of United States of America	U.S. Department of State	United States of America
12217	105	13	105	26	Projections of 100% renewable energy in some countries and overall projections of up to 80% renewable dependency worldwide are not realistic, due to their impact on grid imbalance and the lack of maturity of storage technology. These scenarios should also be compared with the scenarios presented in the UNECE report: The IEA two-degree scenario - By 2050, it projected nuclear energy to be one of the largest low carbon electricity sources, accounting for up to 17 per cent of global electricity demand (2015 edition)	Noted. This section has been substantially revised and reorganized in a balanced manner.	Lavinia Rizea	SN Nuclearelectrica SA	Romania

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
15811	105	13	105	17	"The percentage of electricity produced globally from variable renewable energy, primarily wind and solar power, is likely to grow to around 30-40% (20-30%) in 2030 to limit warming to 1.5°C (2°C) and reach almost 40-70% in 2050 to limit warming to 1.5°C or 2°C. Some authors have argued that wind and solar could produce close to 100% of electricity for individual regions or countries (Hansen et al. 2019), but a range of issues surrounding incorporation of intermittent renewable generation remain unresolved at such high levels of penetration (Section 6.6, Box 6.6)." Lessons from section 6.6 and Box 6.6. would rather suggest here a more precise comment: while there is no consensus on the precise "optimal" percentage of variable renewables, there is a large evidence from research that, as a precautionary judgement, percentage of dispatchable decarbonised generating technologies should remain significant in order to minimize the cost of decarbonization.	Accepted: The text has been revised based on review comments.	Jean-Michel Trochet	EDF group (French Utility)	France
17449	105	13	105	26	Scenarios in the paragraph are not near-term and medium-term as promised in the title of Chapter 6.7. Please remove the paragraph and provide realistic scenarios for the next decade.	Rejected. The paragraph includes near-term and medium-term scenario.	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
61835	105	13	105	26	The discussion on high shares of renewable electricity should be accompanied with similar discussion of high-shares of nuclear electricity, given that they are much more proven and feasible as nuclear is a firm source of power and is therefore much easier to integrate high shares of (e.g. what France has done). Further, it should be discussed that nuclear can produce not just firm low-carbon electricity, but also high-grade industrial process heat, low-temperature heat for district heating and for water desalination as well as affordable high-temperature steam for effective high-temperature hydrogen electrolysis and synthetic low-carbon fuels production. See e.g. Sepulveda et al., 2018, https://doi.org/10.1016/j.joule.2018.08.006; Luderer et al., 2019, https://doi.org/10.1038/s41467-019-13067-8, Brooks, 2012, https://doi.org/10.1016/j.enpol.2011.11.041; Qvist and Brook, 2015, https://doi.org/10.1371/journal.pone.0124074, and Berger et al., 2017, doi:10.1504/ijgei.2017.080766).	Accepted: The text has been revised based on review comments.	Rauli Partanen	Think Atom	Finland
65875	105	13	105	26	There is quite a bit of discussion on the possibility of high shares of variable renewable energy. There should be an equivalent analysis of studies with equivalently high shares of firm low-carbon power. After all, literature contains several studies that point out the importance of having firm low-carbon electricity and energy sources (Sepulveda et al., 2018, https://doi.org/10.1016/j.joule.2018.08.006 ; Luderer et al., 2019, https://doi.org/10.1038/s41467-019-13067-8).	Noted. One of the suggested references is referred to.	Eero Hirvijoki	Aalto University	Finland
5403	105	14	105	14	replace "is likely" by "should". As you know, it's quite unlikely that the objectives you mention will be met.	Rejected. This part is based on the analysis results of the integrated evaluation model, and "likely" is the appropriate word.	Michel SIMON	Retraité/ Pdt d'association	France
78709	105	15	105	18	the wording '... remain unresolved ...' is misleading. This review has provided quite many comments to the linked boxes, as they are distorted and biased. The right wording here would be '… remain under discussioin …' - as solutions are on the table, but not yet accepted by researchers more in favour of nuclear or fossil CCS, but that does not mean 'unresolved' but that it's 'under discussion' which is qualitatively something else.	Noted. The relevant parts have been deleted.	Christian Breyer	LUT University	Finland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
21617	105	20	105	26	It may be useful to highlight that these assumptions include parametric assumptions such as investment costs, but also structural assumptions on e.g. VRE curtailment (as in the previously cited study by Cole et al., 2017), as well as the choice of modelling approach. Our recent review found that global scenarios derived from energy system models project significantly higher average PV adoption than AR5/SR15 scenarios (https://doi.org/10.1038/s41558-021-00998-8).	Accepted. The text has been revised.	Marc Jaxa-Rozen	University of Geneva	France
43617	105	22	105	22	Define acronym for "VRE"	Accepted. The acronym is spelled out.	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy
78711	105	23	105	24	the same is shown by Ram et al. (http://energywatchgroup.org/wp-content/uploads/EWG_LUT_100RE_All_Sectors_Global_Report_2019.pdf ; also part of AR6 scenario database), so that this reference added would provide a more compehensive overview on existing literature	Rejected. The suggested paper is a non-peer-reviewed report and has low priority.	Christian Breyer	LUT University	Finland
43619	105	24	105	25	Partial reptition of line 16, page 105	Noted. The relevant parts have been deleted.	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy
78713	105	24	105	26	this statement is wrong. The authors show 100% renewable studies, but typically NOT 100% VARIABLE renewable solutions - there is a HUGE difference - typically bioenergy and hydropower from reservoirs, but also geothermal energy is included, and none of them is variable. Therefore the sentence shall be corrected in deleting 'variable'. Such studies also exist, but the dominating body in literature on 100% renewables also include the dispatchable options hydropower reservoirs, bioenergy and geothermal energy. Therefore the factual not correct statement shall be corrected.	Accepted. "becomes" is removed.	Christian Breyer	LUT University	Finland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
48149	105	25	105	26	"some national and regional scenarios from energy system models explore 100% variable renewable contributions." Please include some of these papers: (1) Jacobson, M.Z., and M.A. Delucchi, A path to sustainable energy by 2030, Scientific American, November 2009; (2) Jacobson, M.Z., and M.A. Delucchi, Providing all global energy with wind, water, and solar power, Part I: Technologies, energy resources, quantities and areas of infrastructure, and materials, Energy Policy, 39, 1154-1169, doi:10.1016/j.enpol.2010.11.040, 2011; (3) Delucchi, M.Z., and M.Z. Jacobson, Providing all global energy with wind, water, and solar power, Part II: Reliability, System and Transmission Costs, and Policies, Energy Policy, 39, 1170-1190, doi:10.1016/j.enpol.2010.11.045, 2011; (4) Jacobson, M.Z., M.A. Delucchi, Z.A.F. Bauer, S.C. Goodman, W.E. Chapman, M.A. Cameron, Alphabetical: C. Bozonnat, L. Chobadi, H.A. Clonts, P. Enevoldsen, J.R. Erwin, S.N. Fobi, O.K. Goldstrom, E.M. Hennessy, J. Liu, J. Lo, C.B. Meyer, S.B. Morris, K.R. Moy, P.L. O'Neill, I. Petkov, S. Redfern, R. Schucker, M.A. Sontag, J. Wang, E. Weiner, A.S. Yachanin, 100% clean and renewable wind, water, and sunlight (WWS) all-sector energy roadmaps for 139 countries of the world, Joule, 1, 108-121, doi:10.1016/j.joule.2017.07.005, 2017; (5) Jacobson, M.Z., M.A. Delucchi, M.A. Cameron, and B.V, Mathiesen, Matching demand with supply at low cost among 139 countries within 20 world regions with 100% intermittent wind, water, and sunlight (WWS) for all purposes, Renewable Energy, 123, 236-248, 2018; (6) Jacobson, M.Z., M.A. Delucchi, M.A. Cameron, S.J. Coughlin, C. Hay, I.P. Manogaran, Y. Shu, and A.-K. von Krauland, Impacts of Green New Deal energy plans on grid stability, costs, jobs, health, and climate in 143 countries, One Earth, 1, 449-463, doi:10.1016/j.oneear.2019.12.003, 2019. Others include papers by the groups of Breyer, Mathiesen, Diessendorf, Blakers, and others.	Accepted. One of the suggested literature has been referred to.	Mark Jacobson	Stanford University	United States of America
72147	105	25	105	26	An additional scenario that explores 100% variable renewable contribution for Europe is the following reference: M. Victoria, K. Zhu, T. Brown, G. B. Andresen, M. Greiner, Early decarbonisation of the European energy system pays off, Nature communications 11, 6223 (2020) https://www.nature.com/articles/s41467-020-20015-4	Rejected. The suggested literature does not directly address the 100% RE scenario.	Marta Victoria	Aarhus University	Denmark
55873	105	28			Figure 6.30 is not substantiated in the text. More information on how it was derived and the core assumptions should be provided. Other, more recent studies have much higher hydrogen penetrations. Examples include: IEA World Energy Outlook 2020 & Energy Technology Perspectives, Sustainable Development Scenarios (approximately 7-12% H2 by 2050-2070) https://www.iea.org/reports/world-energy-outlook-2020 Bloomberg New Energy Outlook 2020 (~18% H2) https://about.bnef.com/new-energy-outlook/	Noted. The paragraph has been revised based on the review comments.	Government of United States of America	U.S. Department of State	United States of America
2507	106	2	106	2	What is "detei rminant"?	Accepted. Typo fixed.	Taoyuan Wei	CICERO Center for International Climate Research	Norway
10971	106	2	106	2	change "detei rminant" to "determinant"	Accepted. Typo fixed	Dong-Woon NOH	Korea Energy Economics Institute	Republic of Korea
16395	106	2	106	2	change "detei rminant" to "determinant"	Accepted. Typo fixed.	Government of Republic of Korea	Korea Meteorological Administration (KMA)	Republic of Korea

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
17537	106	2	106	2	typo: determinant	Accepted. Typo fixed.	Alaa Al Khourdajie	IPCC	United Kingdom (of Great Britain and Northern Ireland)
43621	106	2	106	2	Replace" detei rminant" with "determinant"	Accepted. Typo fixed.	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy
71755	106	2	106	2	typo "detei rminant"	Accepted. Typo fixed.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
73999	106	2	106	2	typo "determinant"	Accepted. Typo fixed.	Heleno Miguel	Lawrence Berkeley National Laboratory	United States of America
51445	106	7	106	8	in the residential and light transportation sectors, but the industrial and heavy transportation sectors will	Accepted. The relevant paragraph has been revised based on the review comments.	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
69713	106	11	106	13	The main limits to electrification relate to aviation and deep sea shipping. In industry, electrification can reach extremely high levels in substitution of other energy sources (Madeddu, 2020, op.cit.). However, with respect to process emissions, direct electrification is less mature than hydrogen-DRI, and electrification of cement making would not suppress CO2 formation from calcination of limestone.	Accepted. The relevant paragraph has been revised based on the review comments.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
7901	106	12	106	12	much more limited and costly especially in transport and industry mainly -- would suggest narrowing this to 'parts' of transport - as EVs for passenger vehicles are (as mentioned later on the page) a taking market share from liquid fossil fuels	Accepted. The relevant paragraph has been revised based on the review comments.	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
51447	106	12			especially in heavy transport and industry	Accepted. The relevant paragraph has been revised based on the review comments.	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
85791	106	16	106	16	Suggest consistent use of terms: Battery electric vehicles is defined as "EV" here even though the term EV has been used previously in the chapter. A separate section in this chapter defines battery electric vehicles as "BEV". The term "electric vehicle(s)" and "EV" is used interchangeable.	Accepted. "EV" is used in this section.	Government of Australia	Department of Industry, Science, Energy and Resources	Australia

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
70169	106	26			Concerns remain around the feasibility of sustaining industrially complex societies with the EROI levels that are predicted to be the results of large scale conversions to renewable based energy systems. Rapid conversion to renewables based on a Green Growth scenario could result in EROI as low as 3:1 by mid century - levels well below thresholds identified in the literature required to sustain industrial complex societies (Capellán-Pérez et al, 2019). In addition, the transition to renewables could drive substantial re-materialization of the economy, exacerbating biodiversity impacts and risks exceeding the availability of some minerals. https://www.sciencedirect.com/science/article/pii/S2211467X19300926?	Accepted. The relevant paragraph has been revised based on the review comments.	Rayner Andersen	Department of Fisheries and Oceans	Canada
17451	106	27	106	27	Why is CDR the only geo-engineering method mentioned in the Chapter? Please comment other options.	Rejected. This section is about how to offset the remaining emissions, which is a different discussion from other geoengineering options that affects temperature rise, such as solar radiation management.	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
71757	106	27	107	12	Section 6.7.1.4 could underline the role of Demand Response to integrate renewables into the power system	Noted. Demand response fits high renewable scenario, rather than technology options to offset residual emissionsson, it will be dealt with in the energy transition strategies section.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
20221	106	28	106	38	See also: - Gambhir, A., Drouet, L., McCollum, D., Napp, T., Bernie, D., Hawkes, A., ... & Lowe, J. (2017). Assessing the feasibility of global long-term mitigation scenarios. Energies, 10(1), 89. - Johansson, D. J., Azar, C., Lehtveer, M., & Peters, G. P. (2020). The role of negative carbon emissions in reaching the Paris climate targets: The impact of target formulation in integrated assessment models. Environmental Research Letters, 15(12), 124024. - Fuss, S., Canadell, J. G., Ciais, P., Jackson, R. B., Jones, C. D., Lyngfelt, A., ... & Van Vuuren, D. P. (2020). Moving toward Net-Zero Emissions Requires New Alliances for Carbon Dioxide Removal. One Earth, 3(2), 145-149.	Noted. May refer to some of the suggested literature, if relevant.	Nikas Alexandros	National Technical University of Athens	Greece
10973	106	36	106	36	insert "( )" at "Rogelj et al. 2018a"	Accepted.	Dong-Woon NOH	Korea Energy Economics Institute	Republic of Korea
16397	106	36	106	36	insert "( )" at "Rogelj et al. 2018a"	Accepted.	Government of Republic of Korea	Korea Meteorological Administration (KMA)	Republic of Korea
2713	106	43			DAC could be used to provide high purity carbon that could be used for synthetic fuels. So I think this sentences needs to be a bit more exact, like "DAC would use large amounts of electricity rather than generate any electricity. Nevertheless, it can play a role as carbon feedstock provider, for example, in the production of synthethic fuels and thus interacts with the wider energy system in many ways."	Accepted. The text has been revised.	Jan Wohland	ETH Zurich	Switzerland
12031	106	43	106	43	DAC could provide a supply of fuel, but not a net positive gain. See https://carbonengineering.com/wp-content/uploads/2020/04/c9se00479c.pdf https://www.c2g2.net/wp-content/uploads/C2G2-Geoeng-SDGs_20180521.pdf	Accepted. The text has been revised.	Paul Rouse	Carnegie Climate Governance Initiative (C2G) - The Carnegie Council for Ethics and International Affairs	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
71759	106	43	106	48	The ocean - singular form is better suited. Also, not sure how ocean CDR could alter the trajectory and timing of energy sector transitions.	Accepted. Changed to singular form.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
66743	106	47	106	48	Formatting of references to be reviewed	Accepted.	Chiodi Alessandro	E4SMA	Italy
2509	107	1	107	1	In which year will "Both BECCS and DAC are anticipated to be deployed on the demonstration scale"?	Rejected. The comment is out of context.	Taoyuan Wei	CICERO Center for International Climate Research	Norway
8873	107	1	107	12	Kato and Kurosawa (2021, Sustainability Science) also analyses the required scale of BECCS and DACCS at the national scale.	Noted. No need to modify the text.	Etsushi Kato	Institute of Applied Energy	Japan
80647	107	1	107	10	BECCS is further complicated by the fact that it is not carbon neutral in the near-term—with a carbon deficit for many years, generally several decades to a century—that is crucial for mitigating emissions and avoiding hitting the 1.5°C mark. Danielle Venton, Core Concept: Can bioenergy with carbon capture and storage make an impact?, PNAS (2016); Leturcq, P. (2020) GHG Displacement Factors of Harvested Wood Products: the Myth of Substitution, Nature Scientific Reports 10:1–9; Mary S. Booth, Not carbon neutral: Assessing the net emissions impact of residues burned for bioenergy, Environ. Res. Lett. 13 (21 February 2018); Sterman J. D., et al. (2018) Does replacing coal with wood lower CO2 emissions? Dynamic lifecycle analysis of wood bioenergy, Envtl. Research Letters 13(015007):1–10, 1 ("We simulate substitution of wood for coal in power generation, estimating the parameters governing NPP and other fluxes using data for forests in the eastern US and using published estimates for supply chain emissions. Because combustion and processing efficiencies for wood are less than coal, the immediate impact of substituting wood for coal is an increase in atmospheric CO2 relative to coal. The payback time for this carbon debt ranges from 44–104 years after clear-cut, depending on forest type—assuming the land remains forest. Surprisingly, replanting hardwood forests with fast-growing pine plantations raises the CO2 impact of wood because the equilibrium carbon density of plantations is lower than natural forests. Further, projected growth in wood harvest for bioenergy would increase atmospheric CO2 for at least a century because new carbon debt continuously exceeds NPP. Assuming biofuels are carbon neutral may worsen irreversible impacts of climate change before benefits accrue. Instead, explicit dynamic models should be used to assess the climate impacts of biofuels."). Furthermore, even if BECCS were net zero or negative in the relevant next couple of decades, which it is not, large-scale biodiversity development requires vast land-use changes, which may have significant implications for food security and biodiversity. National Academies of Sciences, Engineering, and Medicine, Negative Emissions Technologies and Reliable Sequestration: A Research Agenda.10 (2019) ("Because	Noted. Concerns about large scale implementation of BECCS are touched in the paragraph and mainly dealt with in other sections and chapters.	Durwood Zaelke	Institute for Governance & Sustainable Development	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
80791	107	1	107	10	BECCS is further complicated by the fact that it is not carbon neutral in the near-term—with a carbon deficit for many years, generally several decades to a century—that is crucial for mitigating emissions and avoiding hitting the 1.5°C mark. Danielle Venton, Core Concept: Can bioenergy with carbon capture and storage make an impact?, PNAS (2016); Leturcq, P. (2020) GHG Displacement Factors of Harvested Wood Products: the Myth of Substitution, Nature Scientific Reports 10:1–9; Mary S. Booth, Not carbon neutral: Assessing the net emissions impact of residues burned for bioenergy, Environ. Res. Lett. 13 (21 February 2018); Sterman J. D., et al. (2018) Does replacing coal with wood lower CO2 emissions? Dynamic lifecycle analysis of wood bioenergy, Envtl. Research Letters 13(015007):1–10, 1 ("We simulate substitution of wood for coal in power generation, estimating the parameters governing NPP and other fluxes using data for forests in the eastern US and using published estimates for supply chain emissions. Because combustion and processing efficiencies for wood are less than coal, the immediate impact of substituting wood for coal is an increase in atmospheric CO2 relative to coal. The payback time for this carbon debt ranges from 44–104 years after clear-cut, depending on forest type—assuming the land remains forest. Surprisingly, replanting hardwood forests with fast-growing pine plantations raises the CO2 impact of wood because the equilibrium carbon density of plantations is lower than natural forests. Further, projected growth in wood harvest for bioenergy would increase atmospheric CO2 for at least a century because new carbon debt continuously exceeds NPP. Assuming biofuels are carbon neutral may worsen irreversible impacts of climate change before benefits accrue. Instead, explicit dynamic models should be used to assess the climate impacts of biofuels."). Furthermore, even if BECCS were net zero or negative in the relevant next couple of decades, which it is not, large-scale biodiversity development requires vast land-use changes, which may have significant implications for food security and biodiversity. National Academies of Sciences, Engineering, and Medicine, Negative Emissions Technologies and Reliable Sequestration: A Research Agenda 10 (2019) ("Because	Noted. Concerns about large scale implementation of BECCS are touched in the paragraph and mainly dealt with in other sections and chapters.	Gabrielle Dreyfus	Institute for Governance & Sustainable Development	United States of America
2511	107	3	107	3	Could not understand "...capable of substituting or solid, liquid, and gaseous fossil".	Accepted. The text has been revised.	Taoyuan Wei	CICERO Center for International Climate Research	Norway
69715	107	4	107	5	Besides aviation, the type of freight transport that is not amenable to the use of electricity is deep sea shipping. Ground freight transport is amenable to using electricity.	Noted. Deep sea shipping is a minor player in terms of energy consumption.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
69717	107	10	107	11	"Excess" power production, whatever its exact definition (otherwise curtailed renewable electricity?) is unlikely to suffice to deliver the quantities of "negative emissions" mentioned here, at 4 GtCO2/y and above.	Noted. This text is intended to describe the technical characteristics, not discuss their quantity.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
2513	107	11	107	11	"produce great greater grid flexibility and", where two "great"	Accepted. The text has been revised.	Taoyuan Wei	CICERO Center for International Climate Research	Norway
2715	107	13	108	3	Is this all hypothetical/under development/already implemented? The entire box is very fuzzy.	Noted. Some sentences have been rewritten to make the point clearer.	Jan Wohland	ETH Zurich	Switzerland
18267	107	13	108	3	(Box 6.10) This discussion of measurable indicators should include measurement of land use for energy production, which is an important indicator of ecosystem level impacts of energy production (which in turn has climate implications).	Accepted. Included land use metrics.	Government of United Kingdom (of Great Britain and Northern Ireland)	Department for Business, Energy & Industrial Strategy	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
55875	107	15	107	17	The Global Stocktake is to take stock of the implementation of the Paris Agreement to assess the collective progress towards achieving the purpose of the Agreement and its long-term goals. The outcome of the global stocktake shall inform Parties in updating and enhancing their NDCs, as well as in enhancing international cooperation for climate action. While, if successful, the GST would contribute to narrowing the emissions gap, it is not mandated to make any conclusions or recommendations regarding ways to close the gap. It is important not to over-interpret UNFCCC decisions. The words "... ways to close any remaining gap between countries' Nationally Determined Contributions (NDCs) and the goal will be sought ..." could be replaced with "... its outcome will inform Parties in updating and enhancing their NDCs."	Accepted. The text has been revised as suggested.	Government of United States of America	U.S. Department of State	United States of America
27739	107	37	107	38	Delete "Carbon prices, fuel prices, energy taxes, and energy subsidy could be candidates to indirectly assess the level of climate policy stringency."	Accepted. The sentence has been deleted.	Eleni Kaditi	Organization of the Petroleum Exporting Countries, OPEC	Austria
51449	107	37			Carbon prices, fuel prices, energy taxes, regulatory measures, and energy subsidy	Noted. The relevant sentence has been deleted.	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
71761	107	37	107	38	Next to pricing policies there are also standards/regulatory policies and other policy types	Noted. The relevant sentence has been deleted.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
2515	107	40	107	40	An "is" should be inserted before "how to measure societal"	Accepted. The text has been revised.	Taoyuan Wei	CICERO Center for International Climate Research	Norway
74213	108	5	111	12	This section fails to discuss the investments that need to be made in non-wind and solar carbon free generation including advanced nuclear, CCS, and hydrogen production amongst others.	Accepted. The relevant paragraph has been revised based on the review comments.	Jeffrey Merrifield	Pillsbury Law Firm	United States of America
8893	108	6	108	7	Another place to potentially reference research into energy transition market.	Noted. This section has been revised.	Seth Dunn	ServiceMax	United States of America
74885	108	7	108	18	Whereas it is known the off-grid present opportunity in reaching universal energy access and towards a 1.5oC emission in 2030, there is no indication of status and prospects on financing off-grid electrification. We propose review of the following literatures. Bhattacharyya, S. C. (2013). Financing energy access and off-grid electrification: A review of status, options and challenges. Renewable and Sustainable Energy Reviews, 20, 462–472. https://doi.org/10.1016/j.rser.2012.12.008 GOGLA, & World Bank. (2018). Off-grid solar market trends report, 2018. https://www.lightingafrica.org/wp-content/uploads/2018/02/2018_Off_Grid_Solar_Market_Trends_Report_Full.pdf IEA. (2019). Africa Energy Outlook 2019. www.iea.org/africa2019	Noted. The relationship between sustainability (or energy access) and energy transformation is discussed in Section 7.7.7.	Government of Kenya	Kenya Meteorological Service	Kenya

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
75019	108	7	108	18	Whereas it is known the off-grid present opportunity in reaching universal energy access and towards a 1.5oC emission in 2030, there is no indication of status and prospects on financing off-grid electrification. I propose review of the following literatures. Bhattacharyya, S. C. (2013). Financing energy access and off-grid electrification: A review of status, options and challenges. Renewable and Sustainable Energy Reviews, 20, 462–472. https://doi.org/10.1016/j.rser.2012.12.008 GOGLA, & World Bank. (2018). Off-grid solar market trends report, 2018. https://www.lightingafrica.org/wp-content/uploads/2018/02/2018_Off_Grid_Solar_Market_Trends_Report_Full.pdf IEA. (2019). Africa Energy Outlook 2019. www.iea.org/africa2019	Noted. The relationship between sustainability (or energy access) and energy transformation is discussed in Section 7.7.7.	Government of Kenya	Kenya Meteorological Service	Kenya
64145	108	8	109	2	Figure 6.31 shows USD is 2010 dollars. It may also be mentioned once in the text (preferably in the beginning).	Accepted. The text has been revised.	Ghulam Rasul Athar	Pakistan Atomic Energy Commission	Pakistan
18269	108	12	108	17	(Section 6.7.2.1) The figures here are confusing - they don't seem to add up to the total. Would suggest explaining what the total represents to make it easier to follow.	Accepted. The relevant paragraph has been revised.	Government of United Kingdom (of Great Britain and Northern Ireland)	Department for Business, Energy & Industrial Strategy	United Kingdom (of Great Britain and Northern Ireland)
48151	108	23	108	23	This study estimates the upfront capital cost to transition the world to 100% renewables for all sectors is ~$73 trillion Jacobson, M.Z., M.A. Delucchi, M.A. Cameron, S.J. Coughlin, C. Hay, I.P. Manogaran, Y. Shu, and A.-K. von Krauland, Impacts of Green New Deal energy plans on grid stability, costs, jobs, health, and climate in 143 countries, One Earth, 1, 449-463, doi:10.1016/j.oneear.2019.12.003, 2019.	Noted. Consider the information suggested.	Mark Jacobson	Stanford University	United States of America
18271	108	26	108	27	(Section 6.7.2.1) "would require USD 3.4 (2.4-4.7) trillion from 2020 through 2050". Missing 'per year' - seems to read as a total investment over 30 years rather than a per year investment.	Accepted. The text has been revised.	Government of United Kingdom (of Great Britain and Northern Ireland)	Department for Business, Energy & Industrial Strategy	United Kingdom (of Great Britain and Northern Ireland)
2717	108	29			"a low-carbon energy system" is very vague. Is this compatible with net zero? 1.5°C? 2°C? It looks very weird to give investment with two leading digits, suggesting precision, while not clearly stating what system this investment leads to.	Noted. The relevant sentence has been deleted.	Jan Wohland	ETH Zurich	Switzerland
5405	108	37	108	37	After "integrate these sources, ass : "and develop the system necessary to guarantee the resilience of the network"	Accepted. The text has been revised as suggested.	Michel SIMON	Retraité/ Pdt d'association	France
27741	108	44	108	45	Delete "IEA (2019) supports the importance of electricity investment".	Noted. The text has been revised.	Eleni Kaditi	Organization of the Petroleum Exporting Countries, OPEC	Austria
51451	109	4			Fig 6.31 meaning of C1..C7. Why 4 data points for 2010? Should it not just be one point denoting spending then?	Accepted. The figure has been fixed.	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
9705	109	5	109	8	Note that shifting energy investment portofolio to achieve rapid decarbonization would also have regional distributional impacts in addition to the mentoned global distriutional impacts	Accepted. The text has been revised.	Mustafa Babiker	Saudi Aramco	Saudi Arabia
52265	109	7	109	7	; should be removed.	Accepted.	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
71763	109	7	109	7	(McCollum et al. 2014);. > remove semi-colon	Accepted.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
64425	109	9	109	9	Fig 6.32 shows investment for T&D as being 1/3 to 1/2 of overall investment at various warming levels, and yet the challenges surrounding deploying T&D investment of this magnitude are not discussed in detail in the text throughout Chapter 6. The text is disproportionately focused on generation technologies.	Accepted. The relevant paragraph has been revised.	Curt Bjurlin	Stantec Consulting	United States of America
74001	110	1	110	1	"goal" should be plural ("goals") to match the verb.	Accepted. The text has been fixed.	Heleno Miguel	Lawrence Berkeley National Laboratory	United States of America
9899	110	5	110	7	It is explained in paragraphs 30-35 that "Currently 90% of energy investment is concentrated in high- and upper-middle income countries, but investment needs to grow in the fast-growing lower-middle and low-income countries". Suggestion: It is also helpful for the fast-growing lower-middle and low-income countries if the strategy and the ways to increase the investment in their countries is included in these paragraphs	Noted. The discussion here is in the context of the global level and does not focus on any particular country or region.	Government of Indonesia	Ministry of Environment and Forestry	Indonesia
18273	110	22	111	5	(Section 6.7.2.1) This section is highly relevant to policy makers given it discusses barriers to investment in low carbon energy systems. Therefore suggest its key messages and recommendations should be included in the executive summary and SPM.	Noted. The messages of SPM are selected based on the overall balance of the chapter text.	Government of United Kingdom (of Great Britain and Northern Ireland)	Department for Business, Energy & Industrial Strategy	United Kingdom (of Great Britain and Northern Ireland)
47135	110	22	111	5	Other factors that substantially affect low-carbon investments in a given country include the quality of regulatory institutions, the rule of law, trade openness, the size of the economy, and the magnitude of financial market capitalization.	Accepted. This paragraph has been revised based on the review comments.	Clarence Tolliver	University of Michigan Law School	United States of America
74003	110	22	110	25	This paragraph should be more balanced. Although it is important to remove barriers to facilitate financing climate technologies, recent experience also show us that an extreme financialization of the sector does not necessarily help decreasing emissions.	Accepted. This paragraph has been revised based on the review comments.	Heleno Miguel	Lawrence Berkeley National Laboratory	United States of America
74005	110	26	111	5	It is important to clarify the nature of the risk associated to renewable projects, which comes from 3 main sources of uncertainty: 1) technology maturity (i.e. uncertainty about lifetime, O&M, etc.); 2) weather - market revenue is strongly associated with the ability to predict short and long-term productions; 3) regulatory uncertainty.	Accepted. This paragraph has been revised based on the review comments.	Heleno Miguel	Lawrence Berkeley National Laboratory	United States of America
27743	110	29	110	30	Delete "Climate policy would decrease such downside risks and would help redirection of investment flow from fossil fuels to renewables."	Noted. The sentence has been revised.	Eleni Kaditi	Organization of the Petroleum Exporting Countries, OPEC	Austria
5407	110	30	110	30	replace Renewables" by "low carbon sources"	Accepted. The sentence has been revised.	Michel SIMON	Retraité/ Pdt d'association	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
30735	110	30	110	30	The investment flows should not only be limited to "renewable energy" but to "non fossil fuel energy".	Accepted. The sentence has been revised.	Government of Japan	Climate Change Division - Ministry of Foreign Affairs	Japan
77257	110	30			Consider changing "renewables" to "low-carbon technologies" to broaden the scope.	Accepted. The sentence has been revised.	Giacomo Grasso	ENEA	Italy
15817	111	2	111	5	"Renewable energy technologies are much more sensitive to the increase in financing costs because renewable energy sources, such as CSP, PV, wind, are highly capital intensive, while fossil fuel-based plants are dominated by fuel cost." Actually, this remark is applicable to all other capital-intensive decarbonised technologies (hydro, nuclear, fossil-fuel with CCS, electricity grids and electricity storage technologies such as batteries, pumped-hydro... associated with power generating technologies). See also my remark in Chapter 6 page 25 lines 22-24.	Noted. The sentence has been revised.	Jean-Michel Trochet	EDF group (French Utility)	France
18275	111	6	111	12	(Section 6.7.2.1) This section could be relevant to policy makers, as it discusses investment risks. Suggest it could therefore be expanded to make the key points more detailed and clearer, especially in terms of policy recommendations.	Accepted. The paragraphs have been revised.	Government of United Kingdom (of Great Britain and Northern Ireland)	Department for Business, Energy & Industrial Strategy	United Kingdom (of Great Britain and Northern Ireland)
71765	111	13	116	2	Stranded assets/path dependencies may also occur with renewables, hydrogen etc. if the role of energy efficiency is not promoted energically enough (Energy Efficiency First Principle), hence allowing renewables to take a larger space, at the expense of energy efficiency options.	Taken into account. This has been discussed in section 6.7.3.2	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
2719	111	14	111	15	This sentence borrows a lot from physics jargon and I am not quite sure if it makes a lot of sense. Path dependence and inertia are two separate concepts, right? And I don't quite understand why favorable socio-economic conditions lead to resistance. Maybe rephrasing along the lines of "Path dependence describes decisions taken now that determine future decisions either completely or partially owing to high system inertia." would be better?	Noted. While this is an interesting discussion we have had to limit discussion on this due to space restrictions	Jan Wohland	ETH Zurich	Switzerland
63185	111	14	112	7	The concept of lock-in is recognized as transcending phsyical infrastructure. The concept of socio-technological lock-in is well-known, including the interlinked lock-in of physical infrastructure, energy technologies, and institutions. (Sklarew, J. 2018. "Power Fluctuations: How Japan's Nuclear Infrastructure Priorities Influence Electric Utilities' Clout." Energy Research and Social Science, Volume 41. July: 158-167.)	Taken into account. The concept of lock-in in societal and institutional systems is covered in section 6.7.3.1	Jennifer Sklarew	George Mason University	United States of America
55877	111	21	111	21	Table 6.10 should include geographical lock-in such as developed by Krugman.	Noted. While this is an interesting discussion we have had to limit discussion on this due to space restrictions	Government of United States of America	U.S. Department of State	United States of America
55879	111	21	111	21	Table 6.10 lists Klitkou et al. (2014), but Klitkou does not appear in the reference list. Has there been a general check to make sure that the references cited in the text have the appropriate entry in the references?	Accepted. Reference list modified	Government of United States of America	U.S. Department of State	United States of America
28445	111	24	112	42	6.7.3.1. Societal and institutional inertia - nice to include this section as I believe it is one of the most important factors limiting the speed of the energy transition. In this case also refer to how such aspects are being adressed in the other chapters such as chapter 5	Accepted. Cross referencing has been made to Chapter 5	Naud Loomans	Eindhoven University of Technology	Netherlands

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
18277	112	13	112	17	(Section 6.7.3.1) It might be clearer if culture and 'regulatory embedding' were considered as two separate categories here. They are of course linked, but the drivers are not always the same.	Noted. We have retained the earlier structure due to space constraints.	Government of United Kingdom (of Great Britain and Northern Ireland)	Department for Business, Energy & Industrial Strategy	United Kingdom (of Great Britain and Northern Ireland)
64291	112	43	113	11	Interesting but not business related (Abandoned: Kang, M., D. L. Mauzerall, D. Z. Ma, and M. A. Celia, 2019: Reducing methane emissions from abandoned oil and gas wells: Strategies and costs. Energy Policy, https://doi.org/10.1016/j.enpol.2019.05.045 /// China: Zhou, F., T. Xia, X. Wang, Y. Zhang, Y. Sun, and J. Liu, 2016: Recent developments in coal mine methane extraction and utilization in China: A review. J. Nat. Gas Sci. Eng., 31, 437–458, https://doi.org/https://doi.org/10.1016/j.jngse.2016.03.027.)	Taken into account. Fugitive methane emissions have been covered in sections 6.7.7 and 6.4.2.7	Christian Lelong	Kayrros	United Kingdom (of Great Britain and Northern Ireland)
84111	113	0	115		Consider carefully consistent terminology relating to future emissions from capital stock - it is not "committed" in any normal use of the word, and can create oddities of discussing targets and scenarios that preclude what is already "committed", but is not really committed in any normal congractual or moral sense of the word. Figure TS2.9 uses word "expected" emissions. Other words to consider: projected / assumed / anticipated / … ? My personal inclination would be "anticipated", because it implies that those who financed and built this stock anticipate it operating for years or decades as expected - but their anticipation may be wrong, either because of overt climate policy, or because operating conditions change, maybe because of momentum in renewables, consumer preference for low carbon, or other factors. Try and discuss with Chapter 2 which seemed to veer away from the word committed in the end.	Noted. The word 'committed' is used in conjunction with the literature synthesized in the report.	Michael Grubb	UCL - Institute of Sustainable Resources	United Kingdom (of Great Britain and Northern Ireland)
18279	113	8	113	11	(Section 6.7.3.2) These two sentences are confusing to read because they appear to contradict one another. Suggest rewording.	Accepted. Second sentence has been removed for greater clarity	Government of United Kingdom (of Great Britain and Northern Ireland)	Department for Business, Energy & Industrial Strategy	United Kingdom (of Great Britain and Northern Ireland)
27745	113	9	113	11	Delete "This would likely lead to further scale-back of capital-intensive oil investments and especially to a substantial scale-back of capital investment in onshore tight oil production (Erickson et al. 2015).", as this argument is based on an analysis conducted prior to the pandemic and does not consider latest developments.	Accepted	Eleni Kaditi	Organization of the Petroleum Exporting Countries, OPEC	Austria
15111	113	18	113	20	“China alone accounts for around 40% of the world’s committed emission from infrastructure, with the US, India and EU accounting for roughly 15% each (high confidence).” Please indicate the year, data source and certification of China's carbon emission accounting for 40% of the world.	Rejected. We have noted that the China's committed emissions account for 40% of the world with the reference provided. We do not mean that China currently accounts for 40% of the world's emissions.	Guoquan HU	National Climate Center of China Meteorological Adminstration	China
52267	113	18	113	18	"Carbon is unevenly distributed." Missing a word or something.	Accepted. We have added the word emissions here.	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
85793	113	18	113	18	Suggest references to Australia be removed from this paragraph. None of the literature cited in this paragraph (Tong, Shearer, Pfeiffer) include any references to Australia.	Accepted.	Government of Australia	Department of Industry, Science, Energy and Resources	Australia

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
85795	113	18	113	22	If the USA and EU account for approx. 15% of committed emissions each, then Australia and Japan would account for approx. 3% together. This does not appear to be a meaningful comparison and should be removed.	Accepted.	Government of Australia	Department of Industry, Science, Energy and Resources	Australia
2721	113	19	113	21	Sentence 1: US + EU = 30% Sentence 2: US + EU + Japan + Australia = 33% Conclusion: Japan and Australia do not matter Is that what you are trying to say?^	Noted.	Jan Wohland	ETH Zurich	Switzerland
2723	113	28			Does this Figure compare energy sector emissions with total emissions in the RCPs? Based on this Figure, it seems that we left the RCP85 track in 2000 and are currently ~10Gt/y lower than RCP85 which is in disarray with what really happens (e.g., Schwalm et al 2020). This seeming discrepancy should at least be clarified because otherwise this Figure risks to be misleading. Schwalm, C.R., Glendon, S., Duffy, P.B., n.d. RCP8.5 tracks cumulative CO2 emissions 2.	Noted. While this is an interesting discussion we have had to limit discussion on this due to space restrictions	Jan Wohland	ETH Zurich	Switzerland
84565	113	31	113	31	Please add: "Karlsson, M., Alfredsson E. & Westling N. (2020) Climate policy co-benefits: a review, Climate Policy 20, 292-316. DOI: 10.1080/14693062.2020.1724070".	Accepted.	Mikael Karlsson	KTH Royal Institute of Technology	Sweden
28639	114	7	114	7	Unless fitted with CCS. Work has shown that there is enough CCS CO2 storage capacity for much of the fossil reserves to be used, Budiniset al (2017) "Can CCS unlock unburnable carbon", Energy Procedia V114 p7504, Budinis et al (2018) "An assessment of CCS costs, barriers and potential", Energy Strategy Reviews 22 (2018) 61-81, and IEAGHG (2016) "Can CCS unlock unburnable carbon", IEAGHG 2016-05	Noted. This has been covered in section 6.4.2.5	Tim Dixon	IEAGHG	United Kingdom (of Great Britain and Northern Ireland)
10975	114	9	114	9	insert "( )" at Haelg et al. 2018	Accepted.	Dong-Woon NOH	Korea Energy Economics Institute	Republic of Korea
16399	114	9	114	9	insert "( )" at Haelg et al. 2018	Accepted.	Government of Republic of Korea	Korea Meteorological Administration (KMA)	Republic of Korea
55881	114	16	114	28	The paragraph switches between GW and GtCO2 when comparing stranded assets across different regions and countries. This difference should be clarified and better described.	Accepted. We have reported all metrics in the paragraph now in GW	Government of United States of America	U.S. Department of State	United States of America
10977	114	36	114	36	delete "()("after Joshua and Aloa 2020)(.	Accepted.	Dong-Woon NOH	Korea Energy Economics Institute	Republic of Korea
16401	114	36	114	36	delete "()("after Joshua and Aloa 2020)(.	Accepted.	Government of Republic of Korea	Korea Meteorological Administration (KMA)	Republic of Korea

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
18281	114	39	114	41	(Section 6.7.3.2) "Moreover, several coal mining communities, have significant health and economic burdens thus creating incentives for decarbonisation". This sentence is a little unclear. Suggest adding a little more detail / explanation to help the reader.	Accepted. Sentence modified.	Government of United Kingdom (of Great Britain and Northern Ireland)	Department for Business, Energy & Industrial Strategy	United Kingdom (of Great Britain and Northern Ireland)
27749	114	44	116	2	Box 6.11 to be deleted as it repeats the analysis incorporated in Chapter 3, section 3.5.2.2.	Rejected as stranded assets is an important angle to analysis in energy transitions.	Eleni Kaditi	Organization of the Petroleum Exporting Countries, OPEC	Austria
28675	114	44	116	2	The IRENA 2017 citation in this Box is not correctly present in the bibliography. I presume it is referring to https://www.irena.org/publications/2017/Jul/Stranded-Assets-and-Renewables	Noted. Reference corrected.	Asa Hopkins	Synapse Energy Economics	United States of America
28677	114	44	116	2	This Box fails to address stranded asset risks for natural gas pipeline networks, including in particular natural gas distribution networks to serve end-use customers. These assets are subject to aggressive investment due to low gas prices and replacing older and leakprone pipe, and yet may need to be retired well before their typical 50-70 year lifetime.	Noted. Literature on this topic is just about beginning to emerge.	Asa Hopkins	Synapse Energy Economics	United States of America
28679	114	44	116	2	This Box fails to discuss the potential to mitigate stranded asset risks in the power and pipeline sectors through more rapid depreciation of these capital assets. This is a key difference between risk of stranding man-made capital assets and risks associated with stranding of fossil fuel rsources that cannot be burned. Suggest adding a statement to the mitigation paragraphs that conclude this Box to the effect of "Stranded asset risks for man-made capital ssets could be mitigated by more rapid depreciation and recovery of the invested capital."	Noted. The box focuses on technological solutions to reducing straded aset risks. Financial mechanisms as explained by the reviewer are nascent topics in the literature.	Asa Hopkins	Synapse Energy Economics	United States of America
28681	114	44	116	2	Regarding stranded fossil fuel assets in buildings, this Box fails to reflect the fact that most fossil fuel systems in buildings are due to be replaced between now and 2050 (because they have expected lives of 20 years or less), and that replacement of these assets by non-emitting alternatives (such as electric heat pumps) would mitigate the stranded asset risk. Suggest coordination between this Box and the Buildings chapter.	Noted. The box focuses on the scenarios literature the focus of which is power sector and fossil resources.	Asa Hopkins	Synapse Energy Economics	United States of America
48403	114	44	116	2	Recently studies indicated that stranded asset can be observed in the energy demand sectors due to rapid energy system changes. For example, Oshiro et al. (2020) indicated that energy investment in energy demand sectors can be stranded as well as energy supply infrastructure, while the risk of stranded investment can be reduced by sectoral policies such as subsidy for electrified equipment. * Oshiro, K., Fujimori, S. (2020). Stranded investment associated with rapid energy system changes under the mid-century strategy in Japan. Sustainability Science, in press. doi:10.1007/s11625-020-00862-2	Noted. This literature is nascent. The box focuses on more established literature on the stranded assets topic	Ken Oshiro	Kyoto University	Japan
27747	115	9	115	15	Delete "If warming is to be restricted to 2°C, about 30% of oil, 50% of gas, and 80% of coal reserves will remain unburnable (Meinshausen et al. 2009, Leaton 2011; Leaton Ranger 2013; McGlade et al. 2015; Bauer et al. 2016; Pye et al. 2020; IRENA 2017) (high confidence). Significant stranding of energy reserves would occur in countries that have large oil, gas and coal reserves such as Australia, Brazil, Canada, Indonesia, Mexico, the Russian Federation, Saudi Arabia and South Africa IRENA 2017). High stranded asset risks have also been suggested for Chinese coal production, and the crude oil sector in the Middle East and Latin America (Ansari and Holz 2020)."	Rejected	Eleni Kaditi	Organization of the Petroleum Exporting Countries, OPEC	Austria

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
28641	115	9	115	15	Unless CCS is deployed widely. Work has shown that there is enough CCS CO2 storage capacity for much of the fossil reserves to be used, Budiniset al (2017) "Can CCS unlock unburnable carbon", Energy Procedia V114 p7504, Budinis et al (2018) "An assessment of CCS costs, barriers and potential", Energy Strategy Reviews 22 (2018) 61-81, and IEAGHG (2016) "Can CCS unlock unburnable carbon", IEAGHG 2016-05	Rejected	Tim Dixon	IEAGHG	United Kingdom (of Great Britain and Northern Ireland)
18283	115	11	115	15	(Box 6.11) This section is confusing because it lists Saudi Arabia and Brazil in one sentence and then refers "also" to the Middle East and Latin America. Suggest rewording.	Accepted	Government of United Kingdom (of Great Britain and Northern Ireland)	Department for Business, Energy & Industrial Strategy	United Kingdom (of Great Britain and Northern Ireland)
2335	115	13	115	13	you are missing a (in front of "IRENA 2017)"	Accepted	Nicholas Wagner	International Renewable Energy Agency (IRENA)	Germany
10979	115	13	115	13	insert "(" at "and South Africa IRENA 2017)".	Accepted	Dong-Woon NOH	Korea Energy Economics Institute	Republic of Korea
16403	115	13	115	13	insert "(" at "and South Africa IRENA 2017)".	Accepted	Government of Republic of Korea	Korea Meteorological Administration (KMA)	Republic of Korea
80495	115	36	115	36	When talking about stranded assets, please include as reference point estimates of the economic damage, if these assets are not stranded. https://am.pictet/-/media/pam/pam-common-gallery/article-content/2020/pictet-asset-management/oxford-paper/climate-change-and-emerging-markets-after-covid-19.pdf puts the damages to USD90 trillion to more than USD500 trillion by 2100, and these are not one-off write-offs like stranded assets, but continuing cost.	Noted	Moritz Riede	University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
74215	115	45	115	46	A discussion should be inserted in this section about the potential to retrofit existing nuclear units to produce hydrogen in the off peak time periods, or full time in areas where the units no longer have sufficient demand. https://www-pub.iaea.org/MTCD/Publications/PDF/Pub1577_web.pdf	Noted. The literature suggested by the reviewer is nascent. The box focuses on more established literature on the stranded assets topic	Jeffrey Merrifield	Pillsbury Law Firm	United States of America
28643	115	46	115	48	See also Budinis et al (2017) "Can CCS unlock unburnable carbon", Energy Procedia V114 p7504, Budinis et al (2018) "An assessment of CCS costs, barriers and potential", Energy Strategy Reviews 22 (2018) 61-81, and IEAGHG (2016) "Can CCS unlock unburnable carbon", IEAGHG 2016-05	Noted	Tim Dixon	IEAGHG	United Kingdom (of Great Britain and Northern Ireland)
61837	115	46	116	2	While retrofitting coal plants with CCS is discussed, it should be discussed that China is planning to also use a high-temperature nuclear reactor (HTR-PM) to be a “drop-in replacement” for their super-critical coal plants, making their current fleet of coal plants stranded assets only for the part of the coal boiler, while the other infrastructure (turbine-island, switchyard, transmission lines etc) can be repurposed and reused with the new heat source. See https://www.world-nuclear-news.org/NN-China-plans-further-high-temperature-reactor-innovation-1909171.html	Noted	Rauli Partanen	Think Atom	Finland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
65877	115	46	116	2	In discussing the possibility of stranded coal assets, it might be worth to mention that China plans to counter this with the HTR-PM reactor. One of the design features of this high temperature gas cooled reactor is that it can be retrofitted to the existing coal plants: the steam temperature and turbine technology are similar for both. This will significantly reduce the potential capital losses from the otherwise stranded coal assets.	Noted	Eero Hirvijoki	Aalto University	Finland
17873	115	48	116	2	The statement, "the ability to deploy CCS at scale remains uncertain" is questionable in the context of existing commercial CCS projects around the world, and the increasing pipeline of projects in development. The number of projects currently deployed would suggest the technology can be deployed at scale – the statement needs a qualifier, i.e. "sufficient scale". Reference: Global Status of CCS Report 2020 globalccsinstitute.com/resources/global-status-report/	Noted. The sentence has been revised.	Eve Tamme	Global CCS Institute	Belgium
69719	116	2	116	2	CCS is not the only option to continue using thermal power plants and avoiding turning them into stranded assets. Other options include their conversion to use carbonless fuels such as hydrogen and ammonia, lower-carbon fuels such as solid biomass, and using their alternators as synchronous compensators delivering inertia in systems with very large share of variable renewables. In a net zero emissions world, natural gas peakers and OCGT may still be very helpful, even if burning natural gas and not hydrogen or ammonia, to ensure electricity security during dark doldrums, with purposely low capacity factors. CCGT could be conserved only for their gas turbines; however, another option of using them very efficiently during very short periods would be to use heat delivered by electricity from other renewables (solar or wind) to keep them warm in stand-by mode (when the efficiency of burning gas would otherwise be very low).	Noted.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
74753	116	4	117	32	some regional scale models for phasing out dominant fossil fuel usage to achieve the emission reduction targets should be provided	Noted. While this is an interesting discussion we have had to limit discussion on this due to space restrictions	Debadutta Mohanty	CSIR - Central Institute of Mining and Fuel Research, Dhanbad	India
9707	116	5	116	24	To what extent non-Co2 emissions will affect the fossil fuel energ transitions? Are there trade-offs or the same reduction of fossil fuel CO2 emissions are projected regardless?	Taken into account. Fugitive methane emissions have been covered in sections 6.7.7 and 6.4.2.7	Mustafa Babiker	Saudi Aramco	Saudi Arabia
51453	116	8			38% and 55% for 1.5 and 2.0 C respectively appear very high	Accepted. Text modified	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
2725	116	11			This sentence understates the evidence that is reviewed in the Stranded Assets Box and the preceding subsection. Suggest to delete "may" as it is fairly obvious that new coal infracture does jeopardize reaching 1.5°C.	Noted. Stranded assets box is positioned so as to complement and not repeat this section.	Jan Wohland	ETH Zurich	Switzerland
27751	116	12	116	14	Delete "Compared to coal, oil and gas extraction is more profitable and capital-intensive. This is why strong financial interests pose barriers and keep capital-intensive oil resources in production, even if policy efforts and social organisations call for a transition away from oil (Erickson et al. 2017)."	Rejected. This ststement is based on our synthesis of the reviewed literature	Eleni Kaditi	Organization of the Petroleum Exporting Countries, OPEC	Austria

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
52281	116	15	116	16	There is large ambiguity in the extent to which fossil fuels with CCS would be compatible with the 2°C and 1.5°C targets (medium confidence). This needs to be clarifed in the text similar to other options.	Noted. While this is an interesting discussion we have had to limit discussion on this due to space restrictions	Government of Saudi Arabia	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
15113	116	18	116	21	“others show that unabated coal retirement far outpaces the deployment of coal with CCS (Budinis et al. 2018; Xie et al. 2020)” It is suggested that Change it to “others show that unabated coal retirement far outpaces the deployment of coal with CCS (Budinis et al. 2018; Xie et al. 2020), although CCS retrofitted infrastructure could reduce the risk of asset stranding” Reason: it is a consensus that the coupling of CCUs and coal-fired infrastructure can effectively reduce the loss of stranded assets. Reference: MOST& ACCA21， 2019 Roadmap for CCUS Technology in China (2019). Science press: Beijing.	Rejected. This ststement is based on our synthesis of the reviewed literature	Guoquan HU	National Climate Center of China Meteorological Adminstration	China
51455	116	23	116	24	before 2050 24 (Luderer et al. 2018), provided associated land use emissions are negligible.	Noted. While this is an interesting discussion we have had to limit discussion on this due to space restrictions	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
10981	116	31	116	31	change "(Oei et al. 2020); Grubert and Brandt 2019;" to "(Oei et al. 2020; Grubert and Brandt 2019).	Accepted	Dong-Woon NOH	Korea Energy Economics Institute	Republic of Korea
16405	116	31	116	31	change "(Oei et al. 2020); Grubert and Brandt 2019;" to "(Oei et al. 2020; Grubert and Brandt 2019).	Accepted	Government of Republic of Korea	Korea Meteorological Administration (KMA)	Republic of Korea
69721	116	31	117	1	On the other hand, solar PV electricity from new-built plants is already cheaper for bulk electricity than operating expenses (fuel expenditures included) of coal plants in China and India, which makes the phaseout much less cost-prohibitive.	Taken into account. The regional cost patterns for PV have been discussed in section 6.4.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
43899	117	8	117	9	Natural gas, especially liquefied natural gas, has the potential to be a critical tool in achieving the short-term mitigation targets. As the least carbon-intensive fossil fuel, natural gas is capable of replacing coal as a dominent energy source especiall in developing countries who still find renewable energy development too capital intensive or infeasible. Liquefied natural gas can enable these developing countries to divest from coal and commit to a cleaner, more efficient alternative. However, similar to toher fossil fuels, the risk of stranded natural gas assets are still present and strategic planning for liquefied natural gas deployment is critical.	Noted. While this is an interesting discussion we have had to limit discussion on this due to space restrictions	Vince Davidson Pacañot	University of the Philippines Diliman	Philippines
71767	117	8	117	21	The section suggests that natural gas can have the role of a transition fuel. Gas infrastructure contribute nevertheless to the inertia of the energy system and stranded investments later on.	Noted. While this is an interesting discussion we have had to limit discussion on this due to space restrictions	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
18285	117	9	117	15	(Section 6.7.4) Confusing. Refers twice to peak natural gas as if these are referring to different things. Suggest rewording.	Accepted	Government of United Kingdom (of Great Britain and Northern Ireland)	Department for Business, Energy & Industrial Strategy	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
69723	117	9	117	11	If the peak year mentioned here is that of natural gas consumption, note that in the IEA Sustainable Development Scenario, compatible with 2°C target, natural gas demand would peak around 2025. In the Net Zero Emissions by 2050 chapter (not yet a full scenario) compatible withs 1.5°C target, natural gas demand would by 2030 be lower than in 2019 by 309 Mtoe. (IEA World Energy Outlook 2020)	Accepted. Text modified	Cédric PHILIBERT	Institut Français des Relations Internationales	France
5409	117	16	117	17	replace Renewables" by "low carbon sources", on the two lines. IPCC is not in its rôle when disregarding the nuclear energy.	Accepted.	Michel SIMON	Retraité/ Pdt d'association	France
43623	117	18	117	18	Remove last bracket	Accepted	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy
49761	117	18	117	18	Parenthesis at the end of this line may be removed.	Accepted.	PINAKI SARKAR	CSIR-CIMFR, Dhanbad	India
51457	117	22	117	23	60-90% and 40-70% appear very high for the transport sector. Should this be the heavy transport sector?	Accepted. Text modified	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
69725	117	22	117	32	This paragraph is highly questionnable. Recent modelling efforts suggest a more rapid decrease in oil demand. For example, in the IEA SDS the demand for oil in 2040 is a third less than in 2019 (3006 Mtoe vs. 4525 Mtoe), and while transports accounts currently for 60% of the oil demand it would only account for 40% of the oil demand in 2040, meaning that the oil demand in transports would go down from 2700 Mtoe to 1200 Mtoe by 2040. In the NZE2050 chapter, this reduction in oil demand by one third would arrive by 2030 already. (IEA World Energy Outlook 2020).	Accepted. Text modified	Cédric PHILIBERT	Institut Français des Relations Internationales	France
69727	117	30	117	32	This statement appears unsubstantiated. Electrification of all types of vehicles is the main driver of the reduction in oil demand in the IEA SDS (from 2700 Mtoe to 1200 Mtoe transport demand), while the increasee demand for petrochemicals and in particular plastic packaging prevents an even faster collapse of oil markets. (IEA World Energy Outlook 2020).	Accepted. Text modified	Cédric PHILIBERT	Institut Français des Relations Internationales	France
51459	117	31	117	32	role is limited to the LDV and HDV categories. {But LDV and HDV account for about 2/3 of total transportation energy}	Accepted. Text modified	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
11139	117	33	119	31	In general I like that you focus heavily on policy mixes, rather than specific policies. It would also be useful to descvribe the merging concept of policy sequences, relating this to the transitions dynamics framework presented in Chapter 1. Within the sequence framework, an emerging issue is that of phase-out policies, and whether they are market based (as suggested e.g. by Pahle et al, 2018) or regulatory (as suggested by Rogge and Johnstone 2017). Finally, think this section could be a lot more understandable if there were some more concrete examples. Both Germany and the UK offer this possibilty, and it might be good to expand on the two sentences describing them.	Taken into account - added policy sequencing and other examples	Anthony Patt	ETH Zürich	Switzerland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
18287	117	33	119	31	(Section 6.7.5) It is in general quite difficult for the reader to unravel the key points from Section 6.7.5, which is a potentially policy relevant and important section. Suggest rewording to make this section clearer and to really highlight what the key points are. Some more specific examples, including lessons learnt, would be especially helpful in this regard. More detail in all parts of this section would be potentially important - it is currently rather too high-level and vague.	Taken into account - added details to regional decarbonisation efforts; no further detailed discussion of examples discussed due to space constraints; furthermore, please see policy chapters	Government of United Kingdom (of Great Britain and Northern Ireland)	Department for Business, Energy & Industrial Strategy	United Kingdom (of Great Britain and Northern Ireland)
63187	117	33	119	31	Many national governments do not yet coordinate their policy goals for energy and climate, and lack of such integration can hinder climate change mitigation goals when energy policies pose additional challenges to such goals. (Sklarew D. and J. Sklarew. 2018. Integrated water-energy policy for sustainable development. Foresight and STI Governance 12(4): 10-19. doi: 10.17323/2500-2597.2018.4.10.1)	Accepted - text revised	Jennifer Sklarew	George Mason University	United States of America
78533	117	40	117	47	Decarbonization efforts of Germany and UK are mentioned. But no words about France, Sweden or more recently Ontario. These are all examples of countries to decarbonize their energy system (quickly in decades or less), and for reasonable price with nuclear power plants.	Noted - examples of decarbonisation efforts in countries with heavy reliance on fossil energy	Tomaž Žagar	Faculty for Energy Technology, University of Maribor	Slovenia
5411	117	46	117	46	Add, if you really wish to take Germany as an example : : However, Germany, in spite of heavy investments in wind and solar have only slightly reduced its coal-based production and CO2 emissions, germany is still on the top of the scale in terms of CO2/person,cost of electricity is almost twice higher than in France, and a new 1100 MXe xoal fired plant has just be put on line in 2020.	Noted - no discussion about economic, environmental and social impacts	Michel SIMON	Retraité/ Pdt d'association	France
17453	117	46	117	47	Decarbonization efforts of Germany and UK are mentioned. But no words about France, which has already decarbonized: quickly (2 decades), and for reasonable price with nuclear power plants.	Noted - examples of decarbonisation efforts in countries with heavy reliance on fossil energy	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
11137	118	1	118	1	I think the word "diverse" would be betterl than "fragmented." Fragmented suggests that the diversity is a bad thing, whereas there isn't clarity on this in the research community.	Accepted - text revised	Anthony Patt	ETH Zürich	Switzerland
43901	118	1	118	2	The Nationally Determined Contributions (or NDCs) is an important instrument in combatting climate change (both adaptation and mitigation) on a national level. However, according to the initial NDC Synthesis Report 2021, the greenhouse gas emissions reduction and avoidance measures of the countries who communicated their NDCs are nowhere near the target 45% curbing of emissions by 2030 as released in the SR1.5 report. Since NDCs are country-specific, it is expected that the commitments to be communicated by countries are variable to certain extents, depending on the energy demand, supply, and development plans. However, it is crucial that top GHG-emitting countries (Especially USA and China) must submit the most ambitious and highly-significant mitigation targets to achieve the common goals of the UNFCCC in combatting climate change. Likewise, countries that do not emit copious amounts of GHG emissions in the atmosphere, especially those Non-Annex I countries to the UNFCCC must still deliver an ambitious yet achievable communication to the Convention. Every ton or ppm of greenhouse gases that were removed or prevented from being released could contribute in the global climate action. Solidarity among nations and their peoples is a critical component of a successful mitigation strategy.	Noted - beyond the scope of this chapter (see e.g. chapter on international climate policy)	Vince Davidson Pacañot	University of the Philippines Diliman	Philippines

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
2911	118	10	119	12	Understanding the dynamics of human behaviour can help policy-makers to complement traditional energy poverty alleviation, energy efficiency and renewable energy policy measures with behaviourally informed ones. We must identify, design and implement the policies that can help producing the behavioral changes that are required for the energy systems transformation.	Noted - detailed discussion not possible here due to space constraints but can be found in the next section	Leonardo Barreto	Head of center "EU&International"	Austria
18289	118	10	118	12	(Section 6.7.5) "However, current policy efforts to promote adoption of low-carbon technologies focus mainly on economic incentives but policies can be more cost-effective when they would also target relevant cognitive and motivational factors". Some examples here would potentially be useful. It is also missing a statement of confidence / agreement.	Taken into account - text revised; meta analysis with examples can be found in the reference	Government of United Kingdom (of Great Britain and Northern Ireland)	Department for Business, Energy & Industrial Strategy	United Kingdom (of Great Britain and Northern Ireland)
2913	118	13	118	16	Among others, it is important to integrate a social dimension to energy policy that takes into account the needs of low-income population, addresses energy poverty in its various forms and protects vulnerable consumers while advancing decarbonisation	Taken into account - text revised, distriutional concerns added	Leonardo Barreto	Head of center "EU&International"	Austria
10983	118	13	118	14	make clera the meaning of the sentence	Editoral. Noted	Dong-Woon NOH	Korea Energy Economics Institute	Republic of Korea
12219	118	13	118	28	A special mention should be made regarding the need to ensure a level playing field and objective screening criteria for all low carbon energy sources without giving special benefits to some energy sources over the others as this will lead to market inbalances and increased cost of the transition. As the experience with the EU Taxonomy has shown us what are the damages of having different approaches and assessment criteria to differente energy sources.	Accepted - text revised, added neccessity of comprehensive data, methodology and indicators.	Lavinia Rizea	SN Nuclearelectrica SA	Romania
16407	118	13	118	14	make clera the meaning of the sentence	Editoral. Noted	Government of Republic of Korea	Korea Meteorological Administration (KMA)	Republic of Korea
2915	118	20	118	21	In the industrial sector capital assets tend to have long lifetimes. Retiring them early to switch to alternative technologies would incur very large costs. This makes decarbonisation in this sector difficult. Whenever possible, refurbishment with innovative technologies should be used to reduce their emissions intensity without having to retire the entire facility.	Noted - beyond the scope of the chapter (topic convered in industry chapter; is dicsussed e.g. in Section 11.5.1)	Leonardo Barreto	Head of center "EU&International"	Austria
2917	118	33	118	35	This sentence is not clear. Please explain.	Accepted - text revised	Leonardo Barreto	Head of center "EU&International"	Austria
2919	118	37	118	39	For example, a coordinated implementation of renewable energy and energy efficiency policies is necessary to achieve decarbonistion goals in the buldings sector (e.g. coordinated implementation of the EU renewable energy directive, energy efficiency directive and energy performance of buildings directive)	Accepted - text revised; example cannot be added due to space constraints	Leonardo Barreto	Head of center "EU&International"	Austria
2921	118	37	118	39	For example, cordination between sectoral policies is necessary to achieve sector coupling involving the electrification of heating and cooling in buidlings, transport (e-mobility) and industry sectors while reinforcing the interaction between electricity supply and end-use. Among others, sector coupling requires the reduction of taxes imposed on electricity.	Taken into account - detailed discussion not possible due to space constraints	Leonardo Barreto	Head of center "EU&International"	Austria

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
2923	118	41	118	42	For example, a combination of emission reduction targets and carbon border adjustment mechanisms for competing imports may be required to mitigate carbon leakage and address competitiveness concerns. However, their environmental effectiveness needs to be assesed carefully. Moreover, they may lead to retaliation by trade partners. Thus, also their legal implications needs to be carefully assessed. Specifically, they would have to be made WTO-compatible. That is, they should not be designed only to protect a given region´s industry competitiveness and their environmental effectiveness should be ensured.	Taken into account - combined with other comments on carbon leakage	Leonardo Barreto	Head of center "EU&International"	Austria
10985	118	42	118	42	delete "(" at (Rosendahl et al. 2017)	Editorial. Noted	Dong-Woon NOH	Korea Energy Economics Institute	Republic of Korea
16409	118	42	118	42	delete "(" at (Rosendahl et al. 2017)	Editorial. Noted	Government of Republic of Korea	Korea Meteorological Administration (KMA)	Republic of Korea
2925	119	12	119	15	Distributional effects of policies are of particular importance, particulary in the current situation of economic downturn in which poverty levels and unemployment have substantally increased. On the one hand, there is a need to protect vulnerable populations. On the other hand, a careful balance between climate and social objectives is necessary to obtain political buy-in.	Taken into account - combined with other comments on distributional effects	Leonardo Barreto	Head of center "EU&International"	Austria
2927	119	24	119	27	Current policies should be considered to the extent possible when designing baseline scenarios for analysis of GHG mitigation options. Baseline scenarios, which do not include climate policies, should not be labelled "business as usual" scenarios because this can be misleading (Hausfather, Z., Peters, G., 2020: Emissions – the 'business as usual' story is misleading. Nature, comment, 29 January 2020).	Noted	Leonardo Barreto	Head of center "EU&International"	Austria
20223	119	33	119	36	To underpin: - Turnheim, B., Berkhout, F., Geels, F., Hof, A., McMeekin, A., Nykvist, B., & van Vuuren, D. (2015). Evaluating sustainability transitions pathways: Bridging analytical approaches to address governance challenges. Global Environmental Change, 35, 239-253. - Nikas, A., Lieu, J., Sorman, A., Gambhir, A., Turhan, E., Baptista, B. V., & Doukas, H. (2020). The desirability of transitions in demand: Incorporating behavioural and societal transformations into energy modelling. Energy Research & Social Science, 70, 101780. - Geels, F. W., Berkhout, F., & van Vuuren, D. P. (2016). Bridging analytical approaches for low-carbon transitions. Nature Climate Change, 6(6), 576-583. - Doukas, H., Nikas, A., González-Eguino, M., Arto, I., & Anger-Kraavi, A. (2018). From integrated to integrative: Delivering on the Paris Agreement. Sustainability, 10(7), 2299. - Dermont, C., Ingold, K., Kammermann, L., & Stadelmann-Steffen, I. (2017). Bringing the policy making perspective in: A political science approach to social acceptance. Energy policy, 108, 359-368. - Galende-Sánchez, E., & Sorman, A. H. (2021). From consultation toward co-production in science and policy: A critical systematic review of participatory climate and energy initiatives. Energy Research & Social Science, 73, 101907. - Sorman, A. H., Turhan, E., & Rosas Casals, M. (2020). Democratizing energy, energizing democracy: Central dimensions surfacing in the debate. Frontiers in Energy Research, 1-6.	Noted. Due to space limitation, references are included in the substantial text.	Nikas Alexandros	National Technical University of Athens	Greece

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
2929	119	38	119	44	Participatory policy and decision-making processes involving citizens are helpful in getting people to better understand the complexity of the decision-making and the issues at stake. Citizens can add diverse ideas to the policy process, from their day-to-day experience. Using citizen´s ideas and knowledge, policies and services can be designed to respond to citizens' needs see e.g. Holmes, B., 2011: Citizens' engagement in policymaking and the design of public services. Research Paper no. 1 2011–12. Parliament of Australia. https://www.aph.gov.au/about_parliament/parliamentary_departments/parliamentary_library/pubs/rp/rp1112/12rp01)	Noted, public participation is discussed in 6.7.6.2	Leonardo Barreto	Head of center "EU&International"	Austria
43625	119	45	120	8	Subsidies might fail to be cost-effective due to moral hazard issues, when the recipient of subsidies would have underataken low carbon investments anyway. This is typically the case for subsidies for energy effciency upgrades in buildings or for switching to more fuel efficient cars, when the latter actions are put in place because the object of the upgrade is in need of major repairs or has reached the end of its econmic life anyway . See Alberini, A., Bigano, A. (2015) "How Effective Are Energy-Efficiency Incentive Programs? Evidence from Italian Homeowners". Energy Economics, 52(S1): S76-s85 doi:10.1016/j.eneco.2015.08.021 ; and Alberini, A. Bigano, A, Boeri, M. (2014) Looking for Free-riding: Energy Efficiency Incentives and Italian Homeowners. Energy Efficiency, 7:571–590 DOI 10.1007/s12053-013-9241-7, Springer.	Rejected, as the papers do not clearly support such a statement	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy
15261	120	3	120	3	In the sentence "In many countries,…Similarly a subsidy promoted the installation of solar water heaters in Taiwan." , it is seriously wrong to put Taiwan in parallel with other countries. Taiwan is a province of China, not an independent country. This sentence must be deleted, as well as the corresponding reference (page 139, lines 38-40).	Accepted, the sentence now reads: 'Similarly, a subsidy promoted the installation of solar water heaters in Asia'	Government of China	China Meteorological Administration	China
2931	120	44	120	47	An example of social influencing tools are Living Labs. They allow citizens to interact with new technologies and experiment with new behaviour and can help them accept mitigation technologies and behaviour. As such, they contribute to test and validate innovations and/or to tackle current societal challenges that prevent the adoption of mitigation technologies.	Noted. Living labs can affect behaviour via multiple routes, not necessarily via social influence. So we do not refer to it here, but rather mention them later in section 6.7.6.2 in which we discuss the role of policy trials	Leonardo Barreto	Head of center "EU&International"	Austria
2933	120	44	120	47	Citizen Science has the potential to engage the public in an inclusive manner in climate change. Citizen engagement in research activities can encourage environmentally-friendly action and empower citizens to play an active role. It can also accelerate and enable production of new scientific knowledge, increase public awareness about science, and increase prevalence of evidence-based policy making (iSCAPE, 2020: Citizen Science: a collaborative approach to air pollution control. Policy Briefs from the iSCAPE project funded by the European Union's Horizon 2020 Research and Innovation Programme. https://www.iscapeproject.eu/)	Noted. In line with the mandate of the IPCC, the text is based on an assessment of the litearture, and we refrain from speculating what effects approaches may have	Leonardo Barreto	Head of center "EU&International"	Austria
20083	121	3	121	11	See also: -Doukas, H., Nikas, A., Stamtsis, G., & Tsipouridis, I. (2020). The Green Versus Green Trap and a Way Forward. Energies, 13(20), 5473.	Noted. Due to space limitation, we cannot add more referneces	Haris Doukas	National Technical University of Athens, Greece	Greece

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
2935	121	10	121	11	Energy Communities bring a number of benefits, including generation of local jobs and keeping financial resources in the region, thus contributing to local economic development. They also boost energy citizenship and democratisation of decision-making in energy projects. Community projects generate financial returns for the community, allowing members to have local control over financial resources and profit-sharing (see e.g. Verde, S., Rossetto, N., 2020: The Future of Renewable Energy Communities in the EU. An investigation at the time of the Clean Energy Package. August, 2020. European University Institute and Florence School of Regulation. doi: 10.2870/754736. https://op.europa.eu/fr/publication-detail/-/publication/e421aa35-fe0e-11ea-b44f-01aa75ed71a1).	Noted. We focus on the impacts of policy approaches on behaviour, and given space limitation, are not able to discuss the wider impacts	Leonardo Barreto	Head of center "EU&International"	Austria
9533	121	33	122	35	Recent research on different mechanism of benefit distribution in mitigation projects have produced important insights. For example, efforts by the Danish government to legally mandate financial participation (e.g. share issue) as a form of cost/benefit redistribution have run into local conflicts due to governance mechanisms considered to be unfair (https://doi.org/10.1016/j.enpol.2020.111294). Research has also shown that defining which community) receives benefits from mitigation projects is a significant social and spatial challenge (https://doi.org/10.1016/j.erss.2019.04.002) and can lead to intra-community conflict, worsening social acceptance, if not done transparently and fairly (http://dx.doi.org/10.1016/j.landusepol.2016.08.034).	Accepted. We discuss the impact of revenue distribution and offering compensation in section 6.7.6.2, and included these suggestions there	Patrick Devine-Wright	University of Exeter	United Kingdom (of Great Britain and Northern Ireland)
9535	121	44	121	45	It is asserted here that people only wish to participate in local projects, not macro-level policy or structural change. I am not persuaded that such a generalisation can be inferred from one survey study in the Netherlands (Perlaviciute and Squintini, 2020). The Fridays for Future protests suggest something quite different. And these findings on preferences for participation need to be set against a context where the normative expectation from socio-historical experiences is not to have opportunities to participate in energy or climate policy making - see writings on energy citizenship and passive roles for publics in centralised energy systems (Devine-Wright, 2007). There is clear evidence that when afforded opportunties to engage in public deliberation around both local energy projects and national level systemic changes, citizens enjoy doing so and welcome the opportunity. Citations: Devine-Wright, P. (2007) Energy citizenship: psychological aspects of evolution in sustainable energy technologies. In J. Murphy (Ed.) Framing The Present, Shaping The Future: Contemporary Governance Of Sustainable Technologies. London: Earthscan, pp. 63-86. Pidgeon, N., Demski, C., Butler, C., Parkhill, K., and Spence, A. (2014). Creating a national citizen engagement process for energy policy. Proc.Natl. Acad. Sci. U S A 111 (Suppl. 4), 13606–13613. Devine-Wright, P. and Cotton, M. (2017) Experiencing citizen deliberation over energy infrastructure siting: a mixed method evaluative study. In Stefan Bouzarovski, Martin J Pasqualetti, Vanesa Castán Broto (Eds.) The Routledge Research Companion to Energy Geographies. Oxford: Routledge, pp. 165-177.	Accepted, rephrased. Please note that this statement is indeed based on one study that focused on this issue. Fridays for future is a protest movement, and does not reflect public participation, and Pidgeon et al invited people to participate in a study on citizen engagement.	Patrick Devine-Wright	University of Exeter	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
63189	121	44	121	45	Since communities are affected by siting of low-carbon energy facilities, transparency of the siting process is important for public understanding and support. Such transparency includes both community input into the policy process and access to data from environmental impact assessments. (McCord, G., D. Kanter, J. Sklarew, G. Wu, and M. Jacobson. 2020. "Accelerating Sustainable Land Use Practices in the U.S.," in America's Zero Carbon Action Plan: Roadmap to Achieving Net Zero Emissions by 2050, 262-281. New York: SDSN. https://www.unsdsn.org/Zero-Carbon-Action-Plan)	Noted, the text indicates that people want to be informed about consequences	Jennifer Sklarew	George Mason University	United States of America
2937	122	3	122	6	Participatory policy and decision-making processes involving citizens increase the transparency and accountability of municipal activities but the processes themselves require legitimacy and transparency. The analysis and synthesis of ideas generated during dialogues must be transparent if the exercise is to be legitimate and trusted (Sormani, P., Rosa, P., Belitrandi, D., 2020: Navigating Diversity: Citizen Engagement in and across the EU. EUR 30233 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-19016-5, doi:10.2760/4730, JRC120167).	Noted, the text indicates that people want to be informed about consequences	Leonardo Barreto	Head of center "EU&International"	Austria
55883	122	5	122	5	The use of NOT LOWER THAN could be clarified using GREATER THAN OR EQUAL TO or a similar phrase. The current phrasing is confusing.	Accepted, rephrased	Government of United States of America	U.S. Department of State	United States of America
18845	122	17	126	32	We are missing the references that nuclear could have and is having a significant positive impact in many SDGs areas.	Accepted. References and additional discussion regarding nuclear has been provided	Tomáš Martanovič	Ministry of Industry and Trade	Czech Republic
20225	122	17	123	21	I am not sure I follow the logic/structure of this part; the discussion on costs seems a bit detached from the SD implications. Also, a discussion on future work considering the cost developments tied to the broad sustainable development spectrum can be found in Nikas A., Gambhir A., Trutnevyte E., Koasidis K., Lund H., Thellufsen J.Z., Mayer D., Zachmann G., Miguel L.J., Ferreras-Alonso N., Sognnaes I., Peters G.P., Colombo E., Howells M., Hawkes A., van den Broek M., Van de Ven D.J., Gonzalez-Eguino M., Flamos A., & Doukas H. (2021). Perspective of comprehensive and comprehensible multi-model energy and climate science in Europe. Energy, 215, 119153.	Noted. The discussion here is to discuss first the co-benefits of transitions from the context of monetized costs and then following into a broader SDG discussion	Nikas Alexandros	National Technical University of Athens	Greece
21073	122	17	122	18	There is no reference in this section of the potential of nuclear energy in countries such as China and India that could have a lot of positive impacts on SDG.	Accepted. Please refer to comment 18845	Government of France	Ministère de la Transition écologique et solidaire	France
21075	122	17	122	18	In this section, there is a lot of examples of solar development that comes in addition to the existing energy system rather that in replacement to fossil fuel. This is certainly a welcomed contribution to the mitigation of climate change but it is hardly sufficient. So what is discussed is mostly the benefit of adding available energy. There is no doubt that adding available energy is beneficial to most SDG. However, there is also a strong need for shifting from fossil energy to renewable eneergy, and the impact of such shift to the SDG must also be discussed in fact, one should make a clear distinction between the two (adding and shifting)	Noted. While this is an interesting discussion we have had to limit discussion on this due to space restrictions	Government of France	Ministère de la Transition écologique et solidaire	France
51185	122	17	126	32	"Section 6.7.7 The Costs and Benefits of Energy System Transitions in the Context of Sustainable Development": There is not a single reference in this section to the potential of nuclear energy. It should be included: nuclear energy could have a lot of positive impacts on SDGs in countries such as China and India.	Accepted. Please refer to comment 18845	Eric PROUST	European Nuclear Society (ENS)	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
51187	122	17	126	32	“Section 6.7.7 The Costs and Benefits of Energy System Transitions in the Context of Sustainable Development”: A lot in this section deals with the benefits of increased electrification through solar energy deployment (solar production coming in addition of existing production). However, what is also strongly needed is a SWITCH from fossil fuels to low-carbon energies. And the discussion on the impact of such a switch on SGDs is lacking. It should be added, and a clear disctinction made in the discussion between impact of addition and impact of switch	Noted. While this is an interesting discussion we have had to limit discussion on this due to space restrictions	Eric PROUST	European Nuclear Society (ENS)	France
61839	122	17	126	32	In the section 6.7.7, "The costs and benefits of energy system transitions in the context of sustainable development", there is no discussion of nuclear. Please revise in light of the UNECE 2021 https://unece.org/sustainable-energy/publications/nuclear-entry-pathways pages 21-26) which discusses the many ways that nuclear power supports the SDG goals. Also, the IAEA has very clear stance with respect to the SDGs and a detailed account of the targets and measures to achieve them is available at https://www.iaea.org/sites/default/files/bull573sept2016.pdf. Not discussing these benefits of nuclear energy seems biased, unscientific and not technology neutral.	Accepted. Please refer to comment 18845	Rauli Partanen	Think Atom	Finland
65879	122	17	126	32	In the section 6.7.7, "The costs and benefits of energy system transitions in the context of sustainable development", there should be a discussion of the benefits of nuclear energy. The IAEA has very clear stance with respect to the SDGs and a detailed account of the targets and measures to achieve them is available at https://www.iaea.org/bulletin/57-3. Most importantly, the United Nations Economic Commission for Europe (UNECE) has evaluated nuclear in achieving the SDGs via the United Nations Framework Classification for Resources and the United Nations Resource Management System. The report, available at https://unece.org/sustainable-energy/publications/nuclear-entry-pathways , includes explicit examples of the nuclear applications supporting every single one of the SDGs (see sections 2.2.1-2.2.17 and Figure 2.6). Revise the section accordingly.	Accepted. Please refer to comment 18845	Eero Hirvijoki	Aalto University	Finland
79709	122	17	126	32	Nuclear is never mentioned with regards to its importance with regards to SDG though there is a lot of littérature on the subject (see above line 16): three substantial reports have been written by IAEA (a UN agency) on the topic: 1/ https://www.iaea.org/sites/default/files/np-sustainable-development.pdf (2017) 2/ https://www.iaea.org/bulletin/57-3 (2016) 3/https://sustainabledevelopment.un.org/content/documents/2259iaeasdg-brochure_forweb.pdf (2015). Recently a report has been published by UNEFE https://unece.org/sustainable-energy/publications/nuclear-entry-pathways. Information on nuclear in chapter 17 on nuclear in SDG, does not reflect the existing litterature	Accepted. Please refer to comment 18845	valerie faudon	SFEN	France
79717	122	17	126	32	On SDG9 Production and distribution of electricity are key infrastructure for GDP. Nuclear contributes (Economic Climat, Infrastructure and FDI : Global evidence with new dimensions, International Journal of Economics, 2017)	Accepted. Please refer to comment 18845	valerie faudon	SFEN	France
84497	122	17	122	32	The placement of this section that also involves the benefits of the energy system transitions in the context of sustainable development earlier in the chapter may be considered.	Noted. While this is an interesting discussion we have had to limit discussion on this due to space restrictions	Siir KILKIS	The Scientific and Technological Research Council of Turkey	Turkey
84567	122	22	122	23	Please add the following reference in the sentence ending with "...lens.": "Karlsson, M., Alfredsson E. & Westling N. (2020) Climate policy co-benefits: a review, Climate Policy 20, 292-316. DOI: 10.1080/14693062.2020.1724070".	Accepted	Mikael Karlsson	KTH Royal Institute of Technology	Sweden

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
7741	122	41	122	41	change "outsised" to "outsized"	Accepted	Mahmoud Abu-samha	College of Engineering and Technology, American University of the Middle East	Kuwait
55885	122	43	122	46	This sentence is confusing, specifically the first portion. The intent of this sentence is to state that designing new infrastructure with climate change in mind is less costly than retrofitting existing infrastructure, which is clear from the second portion of the sentence. However, the first portion's relevance to that intent is not clear.	Accepted. Sentence modified.	Government of United States of America	U.S. Department of State	United States of America
1667	122		126		The cost-benefit analysis presented here is very precise, meaningful, realistic and really makes sense for the reader. It can be used with these statements by scientists, managers and politicians alike.	Accepted	David Novak	DIPLOMA Fachhochschule Nordhessen, https://www.diploma.de/, owner of the chair of sustainability	Germany
37215	122		125		No mention about nuclear; section is biased to particular energy source. Nuclear energy, its relevance, role of SMRs in rapid deployment of nuclear power, cost reduction due to factory build and multiplication characteristics of SMRs, closing the fuel cycle to reduce the waste, in general nuclear energy for sustainable development should be elaborated.	Accepted. Please refer to comment 18845	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
29029	123	4	123	7	This statement seems somewhat contradictory. What are the median values?	Noted. While this is an interesting discussion we have had to limit discussion on this due to space restrictions	Jasmin Kemper	IEAGHG	United Kingdom (of Great Britain and Northern Ireland)
79715	123	10			Long-term operation of nuclear plants is a very competitive means to produce electricity today https://www.iea.org/reports/projected-costs-of-generating-electricity-2020	Accepted. Please refer to comment 18845	valerie faudon	SFEN	France
27753	123	19	123	21	Delete "It is important to note that the benefits of mitigation are significant with most countries noticing a gain in GDP in a world with 1.5°C instead of a 2°C warming (Burke et al. 2018; Pretis et al. 2018).", as this argument is inconsistent compared to the analysis presented in Chapter 3 (see for example Figure 3.37).	Accepted	Eleni Kaditi	Organization of the Petroleum Exporting Countries, OPEC	Austria
69729	123	35	123	39	The "tradeoff" does not seem well characterized here. Whatever the efficiency of a plant, adding CC(U)S will in any case increase the cost of electricity and reduce affordability.	Rejected. While this is true, the incremental cost of electricity will generally be higher in lower-efficiency plants as per the literature.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
7743	123	39	123	39	remove "in" after "transmission losses"	Accepted	Mahmoud Abu-samha	College of Engineering and Technology, American University of the Middle East	Kuwait

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
64293	123	40	123	44	There is strong evidence that the cost of methane mitigation in the energy sector is modest. Vented and fugitive emissions can often be eliminated simply by adopting better operating practices. Emissions data from monitoring satellites shows that the methane intensity of the upstream and midstream sectors varies widely between regions, sometimes by a factor of 100:1. The cost of monitoring energy infrastructure and mitigating methane sources is low relative to prevailaing carbon prices and the global warming potential of methane.	Noted. While this is an interesting discussion we have had to limit discussion on this due to space restrictions	Christian Lelong	Kayrros	United Kingdom (of Great Britain and Northern Ireland)
70161	124	3			minerals. Significant concerns remain regarding the locations and scale required to mine the materials required for large-scale energy production. Many of the mining areas (82%) that target materials needed for renewable energy production also overlap with protected areas and remaining wilderness. Mining threats to biodiversity will increase along side the increase in mines that target materials for renewable energy production. It is also possible that the threats to biodiversity due to these mining projects may surpass those averted by climate change mitigation (Sonter et al. 2020). https://www.nature.com/articles/s41467-020-17928-5	Accepted	Rayner Andersen	Department of Fisheries and Oceans	Canada
43627	124	7	124	8	Check consistency with the previous section (Lines 17-20 page 120)	Accepted	Andrea Bigano	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	Italy
20227	124	14	124	26	Also, the discussion on SDGs is very limited. For example, a lot of literature discussing co-benefits with SDG 3, see - Scovronick, N., Budolfson, M., Dennig, F., Errickson, F., Fleurbaey, M., Peng, W., ... & Wagner, F. (2019). The impact of human health co-benefits on evaluations of global climate policy. Nature communications, 10(1), 1-12. - Vandyck, T., Keramidas, K., Kitous, A., Spadaro, J. V., Van Dingenen, R., Holland, M., & Saveyn, B. (2018). Air quality co-benefits for human health and agriculture counterbalance costs to meet Paris Agreement pledges. Nature communications, 9(1), 1-11. - Rauner, S., Bauer, N., Dirnaichner, A., Van Dingenen, R., Mutel, C., & Luderer, G. (2020). Coal-exit health and environmental damage reductions outweigh economic impacts. Nature Climate Change, 10(4), 308-312. - García-Muros, X., Burguillo, M., González-Eguino, M., & Romero-Jordán, D. (2017). Local air pollution and global climate change taxes: a distributional analysis for the case of Spain. Journal of Environmental Planning and Management, 60(3), 419-436. - Van de Ven, D. J., Sampedro, J., Johnson, F. X., Bailis, R., Forouli, A., Nikas, A., ... & Doukas, H. (2019). Integrated policy assessment and optimisation over multiple sustainable development goals in Eastern Africa. Environmental Research Letters, 14(9), 094001. - Forouli, A., Nikas, A., Van de Ven, D. J., Sampedro, J., & Doukas, H. (2020). A multiple-uncertainty analysis framework for integrated assessment modelling of several sustainable development goals. Environmental Modelling & Software, 131, 104795.	Noted. While this is an interesting discussion we have had to limit discussion on this due to space restrictions	Nikas Alexandros	National Technical University of Athens	Greece

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
29919	124	14	125	14	Please consider to add a reference and adress the issue of "cumulative energy demands" that varies enourmosly across low carbon technologies (Modahl et al (2013) - https://www.sciencedirect.com/science/article/pii/S0301421513009294?via%3Dihub	Noted. While this is an interesting discussion we have had to limit discussion on this due to space restrictions	Government of Norway	Norwegian Environment Agency	Norway
51173	124	14	124	26	The first part of the paragraph explains that greater access to, so larger production of, electricity is beneficial to SDGs. Right, but no electricity/energy production is fully carbon-neutral (especially in case of increased production in the short-medium time), so that greater electrification will have an impact on climate. And all exemples given (except the reduction of kerosene) show a NEGATIVE linkage between climate change and other goals. It is therefore wrong to state that "These indicate positive linkages for climate change mitigation with other goals": this sentence should be amended	Rejected. The discussion here is based on understanding the implications of climate goals on other SDGs.	Eric PROUST	European Nuclear Society (ENS)	France
63673	124	18	124	18	In addition to SDG 1, SDG 2.3 also refers to agricultural productivity and incomes of small-scale food producers	Noted. While this is an interesting discussion we have had to limit discussion on this due to space restrictions	Government of Canada	Environment and Climate Change Canada	Canada
31721	124	22	125		P124L22; P125L4; P125L27"improved indoor air quality"- along with SDG 3, SDG 11 (target 11.6) can also be referred. Also see WGIII Chapter 9 Table 9.5 Notes (P59-60 in SOD)	Noted. While this is an interesting discussion we have had to limit discussion on this due to space restrictions	Shreya Some	Ahmedabad University	India
10987	124	23	124	23	delete "(" at "Torero 2017; (Lewis and Severnini 2020)"	Accepted	Dong-Woon NOH	Korea Energy Economics Institute	Republic of Korea
16411	124	23	124	23	delete "(" at "Torero 2017; (Lewis and Severnini 2020)"	Accepted	Government of Republic of Korea	Korea Meteorological Administration (KMA)	Republic of Korea
7745	124	28	124	29	add "HDI" after human development index.	Accepted	Mahmoud Abu-samha	College of Engineering and Technology, American University of the Middle East	Kuwait
63	124	32	125	1	"Improved energy efficiency is interlinked with higher economic growth in Africa (Ohene-Asare et al. 2020; Lin and Abudu 2020)." Comment: See Figure 9 of Heun et al 2019, the first time (ever) that thermodynamic energy efficiency is plotted against GDP, and we see tight linkage betwene growing efficiency and economic growth for both Ghana and UK. REF: 1. Heun MK, Brockway PE. Meeting 2030 primary energy and economic growth goals: Mission impossible? Appl Energy. 2019 Oct;251:112697.	Noted. While this is an interesting discussion we have had to limit discussion on this due to space restrictions	Paul Brockway	University of Leeds	United Kingdom (of Great Britain and Northern Ireland)
12033	125	1	125	3	Requires reference suggest Honegger, M., et al (2018). Carbon Removal and Solar Geoengineering: Potential implications for delivery of the Sustainable Development Goals. Carnegie Climate Geoengineering Governance Initiative, May 2018, New York, U.S. https://www.c2g2.net/wp-content/uploads/C2G2-Geoeng-SDGs_20180521.pdf	Rejected. We have confined most of our synthesis in this section to peer-reviewed literature.	Paul Rouse	Carnegie Climate Governance Initiative (C2G) - The Carnegie Council for Ethics and International Affairs	United Kingdom (of Great Britain and Northern Ireland)
69731	125	2	125	5	On recent technical improvements see e.g. Khan R and I Alam, 2020, A Solar PV-Based Inverter-Less Grid-Integrated Cooking Solution for Low-Cost Clean Cooking, Energies, 13, 5507;	Accepted. Citation added	Cédric PHILIBERT	Institut Français des Relations Internationales	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
51175	125	3	125	3	"electrified cooking heat reduces primary energy requirement": this statement is too general and should be amended: it depends on the way electricity is produced. It may not always be the case when electricity is produced by thermal power plants, which have an efficiency ~30-40%,	Accepted. Text modified	Eric PROUST	European Nuclear Society (ENS)	France
51461	125	10	125	12	Small change in GJ/y/p from 2017 to 2012 for HDI of 0.7 does not suggest quoted 30 to 50 GJ/y/p for 2017 - 1st decade	Accepted. Text modified	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
5413	125	15	125	15	replace Renewables" by "low carbon sources"	Accepted.	Michel SIMON	Retraité/ Pdt d'association	France
27755	125	15	125	15	Delete "phasing out fossil fuels in favor of renewables", as this is only one of the mitigation options considered in the chapter.	Accepted	Eleni Kaditi	Organization of the Petroleum Exporting Countries, OPEC	Austria
27757	125	15	125	34	It should be elaborated that analysis is based on some regional/country case studies and different conclusions may be generated for other countries, considering specific national circumstances. The analysis is also qualitative and not quantitative, and reference should be made to Figure 6.37 and not Figure 6.36.	Noted. While this is an interesting discussion we have had to limit discussion on this due to space restrictions	Eleni Kaditi	Organization of the Petroleum Exporting Countries, OPEC	Austria
51177	125	15	125	16	"Climate mitigation actions, phasing out fossil fuels in favor of renewables, is likely to have considerable positive SDG benefits": Why only when phasing out of fossil fuels is made in favor of renewables? What about other low carbon technologies? Doesn't phasing out fossil fuel in favor of nuclear also has positive SDG benefits??? Should be rephrased as follows: "Climate mitigation actions, phasing out fossil fuels in favor of low-carbon energies, is likely to have considerable positive SDG benefits"	Accepted.	Eric PROUST	European Nuclear Society (ENS)	France
77259	125	15			Replacement of "renewables" with "low-carbon technologies" would extend the scope of the sentence.	Accepted.	Giacomo Grasso	ENEA	Italy
79711	125	15			Climate mitigation actions, phasing out fossil fuels in favor of renewables and nuclear	Accepted.	valerie faudon	SFEN	France
51179	125	20	125	21	“there are large potential employment opportunities that may be created in alternative sectors such as renewables and bioenergy for both skilled and unskilled workers”. Nuclear energy should be included in the exemples of sectors where large potential employment opportunities may be created. In fact, this true for any low-carbon energy technology.	Accepted.	Eric PROUST	European Nuclear Society (ENS)	France
43401	125	21	125	21	Delete "Sustainable transition” pathways have indicated a complete fossil phaseout which could entail numerous other co-benefits."	Rejected. Comment unclear	sadegh zeyaeyan	Head of national center for forecasting and weather hazards management of Islamic Republic of Iran Meteorological Organization (IRIMO)	Iran

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
50307	125	21	125	21	Delete "Sustainable transition" pathways have indicated a complete fossil phaseout which could entail numerous other co-benefits."	Rejected. Comment unclear	Government of Iran	Islamic Republic of Iran Meteorological Organization (IRIMO)	Iran
17455	125	22	125	24	"For instance, fossil fuels are estimated to generate only 2.65 jobs per USD 1M as compared to projected 7.49 from renewables (Garrett-Peltier 2017)." What is the goal: to create huge number of jobs per invested money (low EROI), or to create an energy system where small amount of people will provide energy for the whole population? I hope it is the second. Our civilisation has already passed the phase where majority of population works for food and energy.	Noted. While this is an interesting discussion we have had to limit discussion on this due to space restrictions	Iztok Tiselj	Jozef Stefan Institute & University of Ljubljana	Slovenia
51181	125	22	125	23	"fossil fuels are estimated to generate only 2.65 jobs per USD 1M as compared to projected 7.49 from renewables": There is a obvious contradiction here. If an energy technology creates more jobs per unit of energy produced, one should expect that this energy technology is more expensive since the cost is mostly to pay the people involved). How can one state both together 1/ that renewables are (becoming) competitive and 2/ that it support more jobs?	Noted. While this is an interesting discussion we have had to limit discussion on this due to space restrictions	Eric PROUST	European Nuclear Society (ENS)	France
51183	125	22	125	23	"Consequential energy transitions from fossil fuels to renewables...": add "and nuclear" ("from fossil fuel to renewables and nuclear"). The exemple of China is given to substantiate the original statement and nuclear energy is clearly part of the transition there even though its current share in the Chinese electricity mix is still low. In the EU, Poland, with its energy strategy adopted last month [1] is another clear example [1] https://biznesalert.com/polish-government-adopted-the-energy-strategy-until-2040/	Noted. While this is an interesting discussion we have had to limit discussion on this due to space restrictions	Eric PROUST	European Nuclear Society (ENS)	France
84569	125	22	125	22	Please add the following reference in the sentence ending with "…other co-benefits.": "Karlsson, M., Alfredsson E. & Westling N. (2020) Climate policy co-benefits: a review, Climate Policy 20, 292-316. DOI: 10.1080/14693062.2020.1724070".	Accepted. Citation added	Mikael Karlsson	KTH Royal Institute of Technology	Sweden
55887	125	24	125	25	The sentence is incomplete and, as such, the intent of it cannot be determined.	Accepted. Text modified	Government of United States of America	U.S. Department of State	United States of America
7747	125	25	125	25	replace "It" with "it"	Accepted.	Mahmoud Abu-samha	College of Engineering and Technology, American University of the Middle East	Kuwait
7749	125	25	125	25	Add a point at the end of the sentene.	Accepted.	Mahmoud Abu-samha	College of Engineering and Technology, American University of the Middle East	Kuwait
79713	125	27			Clean air (SDG3 nuclear has prevented deaths from small particles (Pushker A. Kharecha and James E. Hansen, Environmental Science & Technology, 2013)	Accepted.	valerie faudon	SFEN	France
15263	125	28	125	29	In the sentence "…by reducing PM2.5 emissions, thereby reducing premature deaths (notably in China:", China should not be mentioned particularly because China does not stand out in this regard. It is suggested to delete "(notably in China".	Accepted.	Government of China	China Meteorological Administration	China

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
5415	125	29	125	29	replace Renewables" by "low carbon sources"	Accepted.	Michel SIMON	Retraité/ Pdt d'association	France
7751	125	29	125	29	Add one more ")" after He et al. 2020)	Accepted	Mahmoud Abu-samha	College of Engineering and Technology, American University of the Middle East	Kuwait
7753	125	34	125	34	Replace "(Figure 6.36)." with "(Figure 6.37)."	Accepted	Mahmoud Abu-samha	College of Engineering and Technology, American University of the Middle East	Kuwait
7755	125	35	125	35	If the red color in the concentric circles in the right panel can be made more transparent, it would be much better. Right now, the words in the innermost 2 circles are difficult to read.	Taken into account. High resolution figure will be provided during publication	Mahmoud Abu-samha	College of Engineering and Technology, American University of the Middle East	Kuwait
51463	125	36			Caption for Fig 6.37 could include an explanation of the interactions shown	Noted. While this is an interesting discussion we have had to limit discussion on this due to space restrictions	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
8987	126	34	126	34	The answers provided by the three FAQs are very questionable, under several points of view. The “energy transition” depicted in the FAQs addresses some kind of global technology-based change in the energy provision with limited necessity of changing the way the society is globally organized. The Authors should separate more clearly what is a hope, a personal opinion and a fact to rely to.	Taken int account. The point about societal changes has been added. The FAQs are supported by the chapter.	Francesco Gonella	Ca' Foscari University of Venice, Italy	Italy
29921	126	35	126	36	Relevant to also adress and include information about the challenge of energy storage by an increased share of intermittent energy (wind, solar, Run-of-River HP) in this answer.	Rejected. Limited space.	Government of Norway	Norwegian Environment Agency	Norway
8987	126	34	126	34	The answers provided by the three FAQs are very questionable, under several points of view. The “energy transition” depicted in the FAQs addresses some kind of global technology-based change in the energy provision with limited necessity of changing the way the society is globally organized. The Authors should separate more clearly what is a hope, a personal opinion and a fact to rely to.	Taken int account. The point about societal changes has been added. The FAQs are supported by the chapter.	Francesco Gonella	Ca' Foscari University of Venice, Italy	Italy
29921	126	35	126	36	Relevant to also adress and include information about the challenge of energy storage by an increased share of intermittent energy (wind, solar, Run-of-River HP) in this answer.	Rejected. Limited space.	Government of Norway	Norwegian Environment Agency	Norway

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
46521	126	35	126	47	FAQ 6.1.: please avoid "will be" and rather rephrase e.g. "net-zero energy systems can be similar…."	Taken into account. The tone has been changed to be more clear.	Government of Germany	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety International Climate Policy	Germany
9317	126	41	126	47	The part beginning with "In the future…" sounds as if you have a very clear idea of future energy production. But aren't there different development pathways? And might it be helpful if "the future" could be specified? When, in how many years, roughly, will almost all electricity be produced from sources that don't emit CO2? What makes you certain about this?	Taken into account. The tone has been changed to be more clear.	Maike Nicolai	Helmholtz Centre Geesthacht	Germany
7739	126	44	126	45	remove "to" in "more efficiently than to today "	Accepted.	Mahmoud Abu-samha	College of Engineering and Technology, American University of the Middle East	Kuwait
7903	126	44	126	45	to today -- should be today	Accepted.	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
27759	126	46	126	47	Delete "Fundamental to all of these changes is that net-zero energy systems will use little or no fossil fuels.", as this is not supported by the analysis of this Chapter.	Taken into Account. We have modified the language.	Eleni Kaditi	Organization of the Petroleum Exporting Countries, OPEC	Austria
1669	126		127		Three clear and timely questions on this topic and 3 equally precise, clear and understandable answers. Here, too, a standard was set for what the FAQ area should look like. Outstanding.	Noted. Thank you!	David Novak	DIPLOMA Fachhochschule Nordhessen, https://www.diploma.de/, owner of the chair of sustainability	Germany
18291	126	1	126	3	(Section 6.7.7) "CDR and CCUS often create large land and water trade-offs with SDGs, compared to renewables. Large scale CDR and CCUS therefore requires understanding appropriate geographical context to reduce implications on water and food systems". Land use trade-offs are about more than water and food systems. They can also create major trade-offs in terms of impacts on biodiversity and ecosystem services, which in turn can have major implications for climate mitigation and adaptation and other SDGs. Suggest this section should include at least a sentence on such impacts / trade-offs given how critically important they are to sustainable development.	Noted. While this is an interesting discussion we have had to limit discussion on this due to space restrictions	Government of United Kingdom (of Great Britain and Northern Ireland)	Department for Business, Energy & Industrial Strategy	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
29031	126	1	126	16	Recent IEAGHG report (IEAGHG, “Carbon Capture and Storage and the Sustainable Development Goals”, 2020-14, December 2020.) and accompanying submitted paper (Mikunda et al (2020) "CCS and the Sustainable Development Goals", International Journal of Greenhouse Gas Control, submitted 17 Nov 2020) concluded the following, which might be helpful to check and add as appropriate. CCS has a number of positive interactions with the SDGs: ▪ The considerable potential for CCS to immediately decarbonize both the power and industrial sector means that the deployment of CCS is considered indivisible with actions needed to combat climate change and its impacts (SDG13). ▪ CCS plays an enabling role in the provision of reliable, sustainable and modern energy and can support the decarbonisation of industry both through direct emissions reductions but also indirectly through the supply of low carbon power (SDG7). ▪ CCS can promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all and contribute to a decoupling of economic growth from environmental degradation, through the reduction of CO2 emissions (SDG8). ▪ CCS can also enable sustainable infrastructure developments as well as inclusive and sustainable industrialization, provide a boost to innovation systems, (SDG9), and reduce the carbon footprint of cities to make them more sustainable (SDG11). ▪ Through the reduction of CO2 in the atmosphere, CCS can enable the stabilisation of ocean acidification (a key target of SDG14, i.e. SDG14.3). CCS can also have a number of negative interactions with the SDGs: • Lifecycle emissions may result in counteracting or constraining interactions with a number of SDGs (3, 6 and 15). • In a demand-driven scenario, the energy penalty of CCS means that it can be seen as a constraint on meeting energy efficiency targets (SDG7) but this is only if the assumption is that the additional electricity production due to the energy penalty will be supplied by fossil fuels with CCS. In a modern electricity system based on economic	Accepted. Text modified and citation added	Jasmin Kemper	IEAGHG	United Kingdom (of Great Britain and Northern Ireland)
28645	126	3	126	4	This is incorrect on CCS and on DACC. On DACC Realmonte actually says the opposite for DACC "land and water use is significantly reduced compared to biological NETs" summarised in Fig 6 in his paper. For CO2 capture, water increase is not necessarily so. The water use of CO2 capture can be managed to not increase, see references: Giannaris, S. et al (2020). “Implementing a second generation CCS facility on a coal fired power station”, Greenhouse Gases: Science and Technology, 10(3), 506-518; Magneschi et al (2017) "The Impact of CO2 Capture on Water Requirements of Power Plants", GHGT-13, Energy Procedia 114 6333-6347 ; IEAGHG (2020) “Understanding the cost of reducing water usage in coal and gas fired power plants with CCS”, IEAGHG 2020-09; IEAGHG (2011) "Evaluation and Analysis of Water Usage of Power Plants with CO2 Capture" IEAGHG 2010/05; IEAGHG (2020) "CCS and the Sustainable Development Goals", IEAGHG 2020-14; Mikunda et al (2020) "CCS and the Sustainable Development Goals", International Journal of Greenhouse Gas Control (submitted 17 Nov 2020); also IPCC (2018) SR1.5 Chap 5 p500 which cites Magneschi. The papers cited here in SOD Chp6 (Rosa, Byers) whilst recent (2019,2016) have been checked and found to have chosen water use assumptions based only on papers from 2010 and 2011 (Rosa), 2010,2011,2012 (Byers) and so are out of date.	Accepted. Text modified	Tim Dixon	IEAGHG	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
29033	126	3	126	4	Regarding the water issues in particular: the water use of CO2 capture can be managed to not increase, see references: Giannaris, S. et al (2020). “Implementing a second generation CCS facility on a coal fired power station”, Greenhouse Gases: Science and Technology, 10(3), ; IEAGHG (2020) “Understanding the cost of reducing water usage in coal and gas fired power plants with CCS”, IEAGHG 2020-09; IEAGHG (2011) "Evaluation and Analysis of Water Usage of Power Plants with CO2 Capture" IEAGHG 2010/05.	Accepted. Text modified	Jasmin Kemper	IEAGHG	United Kingdom (of Great Britain and Northern Ireland)
10989	126	4	126	4	make clear "Additionally, Similarly"	Accepted. Text modified	Dong-Woon NOH	Korea Energy Economics Institute	Republic of Korea
16413	126	4	126	4	make clear "Additionally, Similarly"	Accepted. Text modified	Government of Republic of Korea	Korea Meteorological Administration (KMA)	Republic of Korea
17851	126	4	126	6	The production of high salinity brines is produced only under particular conditions (high existing pressure). Moreover, regulators generally require re-injection of brine, eg. Gorgon Co2 injection project. Current entry reads as if all storage projects require brine production. References: https://www.dmp.wa.gov.au/Petroleum/Gorgon-CO2-injection-project-1600.aspx	Noted. While this is an interesting discussion we have had to limit discussion on this due to space restrictions	Eve Tamme	Global CCS Institute	Belgium
17853	126	4	126	6	Consistency: geological carbon sequestration is used here. Throughout chapter geologic storage is used	Noted. Both storage and sequestration have been used in similar contexts.	Eve Tamme	Global CCS Institute	Belgium
28647	126	4	126	7	Actually, those two papers cited (Arena and Klapperich) say that if brine is extracted from CO2 storage projects, the brine can be desalinated to provide drinking water, so this should be a positive statement not the negative one here. Also see IEAGHG (2012) "Extraction of formation water from CO2 storage", IEAGHG 2012-12. In addition, of the 19 large-scale operational projects, there is only one practicing brine extraction from CO2 storage and that is the Gorgon project in Australia, and that project re-injects into another deep geological formation, not the environment, so this statement on brine extraction is misleading. See GCCSI Global Status report 2020 for information on Gorgon. If it was an operation practice, the CCS regulations require environmental impact assessments and would pick this up (Dixon et al (2015) "Legal and regulatory developments on CCS", International Journal on Greenhouse Gas Control 40 (2015) 431-448 .	Accepted. Text modified	Tim Dixon	IEAGHG	United Kingdom (of Great Britain and Northern Ireland)
51465	126	13	126	14	large-scale CDR could also open up the potential for low-carbon transport and urban energy use { how?}	Accepted. Text modified	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
71769	126	17	126	32	Demand response options are cheaper contributors to intermittent energy sources such as wind/PV, as compared to hydrogen or storage	Taken into account. Cost characterizations of different mitigation options have been provided in section 6.4.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
10991	126	24	126	24	delete "(" at "(Section 6.4"	Accepted	Dong-Woon NOH	Korea Energy Economics Institute	Republic of Korea
16415	126	24	126	24	delete "(" at "(Section 6.4"	Accepted	Government of Republic of Korea	Korea Meteorological Administration (KMA)	Republic of Korea

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
7757	126	27	126	27	add "activity" after "solar" in "patterns of solar and wind"	Accepted	Mahmoud Abu-samha	College of Engineering and Technology, American University of the Middle East	Kuwait
4839	127	1	127	14	FAQ 6.2 The answer conflicts with the IPCC (2011) SRREN report, and with the observable progress in renewable energy technologies (www.irena.org). The statements “Only some of the energy from renewable sources can be captured at reasonable costs; other low- or zero-emissions options, such as nuclear power or fossil energy with carbon dioxide capture and storage (CCUS), may be more viable in some circumstances” & “… and hydro-power are all “intermittent”,” are flawed, unfounded, to totally wrong (dam hydropower is the source for continuous adjustment of AC frequency in integrated power systems). The FAQ 6.2 answer mainly serves to maintain the triptych mantra “RE, nuclear and CCS” as juxtaposed low-carbon options for the future. This mantra is outdated and spreads deception because nuclear and fossil fired power with CCS are too expensive for future power generation. They are no complements to renewable power from natural currents (wind, light, water), but incumbent barriers for their fast deployment.	Taken into Account. The language has been adjusted.	Aviel Verbruggen	University of Antwerp	Belgium
37005	127	1	127	14	It is important to give a realistic concept about the intermittent of solar energy and wind energy. Due to the intermittent of these energies, a system will not be able to generate energy alone. It will need a baseload energy net-zero carbon emission, as the nuclear one, to compensate the number of hours along the year in which those renewable energies are not working.,	Taken into Account. The language has been adjusted.	Emilio Minguez	Universidad Politécnica de Madrid (UPM)	Spain
71771	127	1	127	14	The section should mention the role of demand response options and storage (or more generally: flexibility enablers including better forecast of renewables, technology portfolios, spatial integration of renewables etc) to stablise intermittent renewable sources.	Taken into account. We mention changes in the way that energy is used. But there simply isn't room to get into the details of demand response.	Philippe Tulkens	European Union (EU) - DG Research & Innovation	Belgium
78715	127	1	127	14	the answer is biased against 100% renewables, as there exists research clearly concluding that 100% renewables for the entire energy system is well possible, i.e. technically feasiable and economically viable, for the entire energy-industry system. This is documented in Jacobson et al. (https://www.sciencedirect.com/science/article/pii/S2590332219302258), Bogdanov et al. (https://www.sciencedirect.com/science/article/pii/S0306261920316639), Ram et al. (http://energywatchgroup.org/wp-content/uploads/EWG_LUT_100RE_All_Sectors_Global_Report_2019.pdf) and with an overview in Hansen et al. (https://www.sciencedirect.com/science/article/pii/S0360544219304967); the mentioned Bogdanov et al. article discusses in detail how an energy-industry system can be based on 100% renewables. Such literature findings have to be covered by the statements. In addition, a recent report commissioned by the German Energy Agency has clearly stated that all fuels and chemicals can be fully based on 100% renewables without any need for bioenergy (https://www.powerfuels.org/fileadmin/powerfuels.org/Dokumente/Global_Alliance_Powerfuels_Study_Powerfuels_in_a_Renewable_Energy_World.pdf); thus the final sentence require enlargement to the entire energy system, and not only electricity - which is a fundamental and qualitative difference.	Rejected, but also Taken into Account. We have adjusted the language about 100% renewable energy systems.	Christian Breyer	LUT University	Finland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
80137	127	1	127	5	I appreciate the editorial choice to include wave energy capture as a potential emerging technology; perhaps this could be expanded on a bit further, in regard to how this technology is distinct from tidal systems discussed elsewhere in this chapter	Noted. We have made it a little more general.	Robin Happel	Yale Center for Environmental Law & Policy	United States of America
69733	127	2	127	4	While there is no mature ocean waves technology available today, tidal energy and "free cooling" or heat from oceans are available technologies, though still under development with new options (such as in-stream turbines for tidal energy in tidal basins or lagoons).	Noted. We have made it a little more general.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
80649	127	2	127	12	Bioenergy is further complicated by the fact that it is not carbon neutral in the near-term—with a carbon deficit for many years, generally several decades to a century—that is crucial for mitigating emissions and avoiding hitting the 1.5°C mark. Danielle Venton, Core Concept: Can bioenergy with carbon capture and storage make an impact?, PNAS (2016); Leturcq, P. (2020) GHG Displacement Factors of Harvested Wood Products: the Myth of Substitution, Nature Scientific Reports 10:1–9; Mary S. Booth, Not carbon neutral: Assessing the net emissions impact of residues burned for bioenergy, Environ. Res. Lett. 13 (21 February 2018); Sterman J. D., et al. (2018) Does replacing coal with wood lower CO2 emissions? Dynamic lifecycle analysis of wood bioenergy, Envtl. Research Letters 13(015007):1–10, 1 ("We simulate substitution of wood for coal in power generation, estimating the parameters governing NPP and other fluxes using data for forests in the eastern US and using published estimates for supply chain emissions. Because combustion and processing efficiencies for wood are less than coal, the immediate impact of substituting wood for coal is an increase in atmospheric CO2 relative to coal. The payback time for this carbon debt ranges from 44–104 years after clear-cut, depending on forest type—assuming the land remains forest. Surprisingly, replanting hardwood forests with fast-growing pine plantations raises the CO2 impact of wood because the equilibrium carbon density of plantations is lower than natural forests. Further, projected growth in wood harvest for bioenergy would increase atmospheric CO2 for at least a century because new carbon debt continuously exceeds NPP. Assuming biofuels are carbon neutral may worsen irreversible impacts of climate change before benefits accrue. Instead, explicit dynamic models should be used to assess the climate impacts of biofuels."). Furthermore, even if BECCS were net zero or negative in the relevant next couple of decades, which it is not, large-scale biodiversity development requires vast land-use changes, which may have significant implications for food security and biodiversity. National Academies of Sciences, Engineering, and Medicine, Negative Emissions Technologies and Reliable Sequestration: A Research Agenda,10 (2019) ("Because	Noted. We are limited in how much space we can use. So only some issues can be raised.	Durwood Zaelke	Institute for Governance & Sustainable Development	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
80793	127	2	127	12	Bioenergy is further complicated by the fact that it is not carbon neutral in the near-term—with a carbon deficit for many years, generally several decades to a century—that is crucial for mitigating emissions and avoiding hitting the 1.5°C mark. Danielle Venton, Core Concept: Can bioenergy with carbon capture and storage make an impact?, PNAS (2016); Leturcq, P. (2020) GHG Displacement Factors of Harvested Wood Products: the Myth of Substitution, Nature Scientific Reports 10:1–9; Mary S. Booth, Not carbon neutral: Assessing the net emissions impact of residues burned for bioenergy, Environ. Res. Lett. 13 (21 February 2018); Sterman J. D., et al. (2018) Does replacing coal with wood lower CO2 emissions? Dynamic lifecycle analysis of wood bioenergy, Envtl. Research Letters 13(015007):1–10, 1 (“We simulate substitution of wood for coal in power generation, estimating the parameters governing NPP and other fluxes using data for forests in the eastern US and using published estimates for supply chain emissions. Because combustion and processing efficiencies for wood are less than coal, the immediate impact of substituting wood for coal is an increase in atmospheric CO2 relative to coal. The payback time for this carbon debt ranges from 44–104 years after clear-cut, depending on forest type—assuming the land remains forest. Surprisingly, replanting hardwood forests with fast-growing pine plantations raises the CO2 impact of wood because the equilibrium carbon density of plantations is lower than natural forests. Further, projected growth in wood harvest for bioenergy would increase atmospheric CO2 for at least a century because new carbon debt continuously exceeds NPP. Assuming biofuels are carbon neutral may worsen irreversible impacts of climate change before benefits accrue. Instead, explicit dynamic models should be used to assess the climate impacts of biofuels.”). Furthermore, even if BECCS were net zero or negative in the relevant next couple of decades, which it is not, large-scale biodiversity development requires vast land-use changes, which may have significant implications for food security and biodiversity. National Academies of Sciences, Engineering, and Medicine, Negative Emissions Technologies and Reliable Sequestration: A Research Agenda,10 (2019) (“Because	Noted. We are limited in how much space we can use. So only some issues can be raised.	Gabrielle Dreyfus	Institute for Governance & Sustainable Development	United States of America
37731	127	6	127	8	To say that nuclear power may be more viable in some circumstances is an understatement. It will be viable in all circumstances. Emphasis should be to say that we should have a broad portfolio of energy technologies and include all low-carbon energy technologies that is hydro, nuclear, solar and wind.	Taken into Account. The language has been changed.	Ravi B Grover	Homi Bhabha National Institute	India
78251	127	6	127	8	Omission - Nuclear energy has proven to be viable in several circumstances and applications. Due emphasis may be given to nuclear as a clear air energy.	Taken into Account. The language has been changed.	Reetesh Chaurasia	Department of Atomic Energy, Government of India	India

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
85443	127	6	127	7	"Only some of the energy from renewable sources can be captured at reasonable cost". This is simply flat-out wrong. A system on 100% renewable energy has many challenges but capturing solar and wind at reasonable cost is not one of them. Actually the whole FAQ reads as an attempt to please everybody by someone with limited knowledge of renewables. There are now about 400 paper that show (mostly for different countries) that systems using 100% renewables are possible at reasonable costs when seasonal storage and sector coupling are included in the model. Still: large challenges in terms of storage (especially seasonal storage), electricity grids (that need to become smart), residential heat (that many homes cannot easily switch) and industrial processes (that often require specific feedstock and rely on cheap fossil heat). So it's entirely possible to placate the other parties without giving wrong information about renewables. See also page 83 line 17-30 and box 6.6 on page 84-86. I would propose something along the lines of: "Renewable energy technologies harness energy from natural sources that are continually replenished, for example, from the sun (solar energy), the wind (wind energy), plants (bioenergy), rainfall (hydropower), or even ocean waves (wave energy). The energy from these sources exceeds the world's current and future energy needs many times. Research increasingly indicates that systems using only renewable viable against against acceptable or even lower costs in many countries. This is mainly the result of large and ongoing price reductions in solar, wind and storage in the form of batteries (for daily storage) and synthetic fuels (for seasonal storage). However, not all countries have equal access to renewable resources. Also, the storage needed to overcome the intermittend (fluctuating) nature of solar and wind is still relatively expensive and the electricity grid will need to become smarter and stronger. Another problem is that some demand (for examply heat in the build environment and industry) is hard to electrify. Bioenergy is an ideal complement to solar and wind because it is easy to store and consequently available on demand. However, it may	Noted. We have adjusted the language around 100% renewable energy systems.	Auke Hoekstra	Eindhoven University of Technology	Netherlands
82325	127	9	127	11	Add "run-of-river" to hydropower in this sentence (in countries like Sweden and Norway most of the hydro plants have a smaller all larger dam next to the hydro power plant). New sentence: Important sources such as solar energy, wind energy, and run-of-river hydropower are all "intermittent", meaning that they cannot provide energy at all times.	Rejected. Too detailed.	Anna Krook-Riekkola	Luleå University of Technology	Sweden
69735	127	10	127	10	"Variable" would be a more appropriate characterisation than "intermittent" for solar energy and wind energy, and even more so hydropower.	Taken into account. We have gone even more explantory with the text.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
77393	127	10	127	10	delete "hydropower" in this sentence. Hydropower is considered dispatchable, not intermittent	Taken into account. Language has been changed.	Atle Harby	SINTEF Energy Research	Norway
78485	127	12	127	13	This sentence "For all of these reasons, it is unlikely that most future energy systems will rely entirely on renewable energy sources." looks like a contradiction to many references and studies cited in this chapter. Is this a leftover from the first draft? Please remove this sentence, it is too vague and unsubstantiated.	Rejected. The chapter clearly discusses how it is unlikely that future energy systems will be powered entirely by renewable energy.	Pietro Altermatt	Trinasolar, Changzhou, China	Germany
9319	127	13	127	14	I would suggest to move the final sentence to the beginning of the text because it includes the most important message of this FAQ.	Rejected. We do not agree.	Maike Nicolai	Helmholtz Centre Geesthacht	Germany

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
55889	127	13	127	14	Research also shows that removing options from the portfolio makes achieving targets more difficult. What does "indicating that it will be viable" mean? If "viable" is meant to indicate a political judgment that such a program is politically viable, that seems outside the scope of IPCC WGIII. Suggest the more neutral construction of "may be possible". So the sentence could read something like: "While unnecessary narrowing of portfolios may make it more difficult to achieve climate goals, research is increasingly indicating that it may be possible, in many circumstances, to produce most or all electricity from renewable energy."	Taken into account. The language has been changed.	Government of United States of America	U.S. Department of State	United States of America
77261	127	13	127	14	The last sentence is highly questionable per se, and in contrast with the rest of the chapter, where it is stated that a 100% renewables scenario is not viable.	Taken into account. We have removed the detailed point about electricity, since there isn't room to do it justice.	Giacomo Grasso	ENEA	Italy
85797	127	13	127	14	Please review for consistency: This sentence says research is increasingly indicating that it will be viable to produce most or all electricity from renewables. This is inconsistent with the analysis elsewhere in the document, e.g. Box 6.6 or p105 lines 17-18, which provide a more cautious analysis. As elsewhere, if predictions are being made, they should be given a clear and well-defined probability statement as well "high confidence" etc.	Taken into account. We have removed the detailed point about electricity, since there isn't room to do it justice.	Government of Australia	Department of Industry, Science, Energy and Resources	Australia
5417	127	14	127	14	FAQN° is much more impartial than most of the articles in this chapter. Congratulations. Should you replace "most or all" by " a significant part ", it would be perfect. IPCC cannot let the reader imagine than 100%of the world electricity wil be produced by renewables in the foreseable future. It woul be a lie, and a moral fault.	Noted. And agreed.	Michel SIMON	Retraité/ Pdt d'association	France
9321	127	15	127	18	The question and the first three lines of this FAQ give the impression that decarbonisation and an elimination of emissions are synonyms. Is this correct? And are you referring to all kinds of emissions? Or do they need clarification?	Taken into account. Text has been revised.	Maike Nicolai	Helmholtz Centre Geesthacht	Germany
46523	127	15	127	28	FAQ 6.3: this FAQ uses language that can be interpreted as being policy-prescriptive. Please avoid phrases like "must be eliminated" or "need to be".	Accepted	Government of Germany	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety International Climate Policy	Germany
85799	127	22	127	24	These remarks confuse the objective (eliminating emissions) with the means " retiring existing coal-fired power". CCUS remains relevant to zero emissions; the statement here is inconsistent with analysis elsewhere in the chapter, for example 6-44 lines 38 et seq. or on the very same page, 6-127 line 8.	Taken into account. The language has been adjusted.	Government of Australia	Department of Industry, Science, Energy and Resources	Australia
69737	127	23	127	23	Retiring or converting existing coal-fired power plants to combust or co-combust ammonia, solid biofuels or hydrogen, or being used as synchronous converters, and/or refurbished with renewable heat storage in order to be used with low capacity factors while keeping good efficiency despite many hours in stand-by mode.	Taken into account. The language has been adjusted.	Cédric PHILIBERT	Institut Français des Relations Internationales	France
15813	127	24	127	24	"Limiting the construction of new gas-fired power plants". For the very same reason, we should limit the construction of new gas heating systems on final energy consumer side. This kind of action has already been undertaken in countries like The Netherlands or the United Kingdom.	Noted. We don't have space to discuss every option.	Jean-Michel Trochet	EDF group (French Utility)	France

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
51467	127	24	127	25	installing electric heaters (“heat pumps”) in homes and businesses and improving their insulation;	Noted. We don't have space to discuss every option.	Nick Jelley	Physics Department University of Oxford	United Kingdom (of Great Britain and Northern Ireland)
37217	127		127		The role of Nuclear energy for the zero carbon energy system must be elaborated like building a large numbers of SMRs	Noted. We don't have space to discuss every option.	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37219	127		127		Advancements in the SMRs design and associated fuel cycle technologies would play key role	Noted. We don't have space to discuss every option.	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
37221	127		127		to decarbonise the energy system	Noted. We don't understand this comment	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
4841	128	1	203	6	References used in the comments (except IPCC(2011) and IRENA(2019c, 2020d) in the list): Gillinsky, V. (2020). The US government insurance scheme for nuclear power plant acci-dents no longer makes sense. Bulletin of the Atomic Scientists: www.thebulletin.org Haas, R., Mez, L., Ajanovic, A. eds, The Technological and Economic Future of Nuclear Power. Energy Policy and Climate Protection series. Springer VS Open Access https://www.springer.com/gp/book/9783658259860 Markard, J., Bento, N., Kittner, N., & Nuñez-Jimenez, A. (2020). Destined for decline? Exam-ining nuclear energy from a technological innovation systems perspective. Energy Research & Social Science, 67, 101512. https://doi.org/10.1016/j.erss.2020.101512 Schneider, M., Froggatt, A. (2020). The World Nuclear Industry Status Report 2019. Yearly edition: www.worldnuclearreport.org Smith, K.R. et al. (2012). Energy and Health, chapter 4, pp. 255-324 in Global Energy As-sessment. Cambridge University Press; www.globalenergyassessment.org Verbruggen, A. (2008). Renewable and nuclear power: A common future? Energy Policy 36: 4036-4047 Verbruggen, A., Di Nucci, M.R., Fischedick, M., Haas, R., Hvelplund, F., Lauber, V., Lo-renzoni, A., Mez, L., Nilsson, L.J., del Rio Gonzalez, P. Schleich, J., Toke, D. (2015). Eu-rope’s electricity regime: Restoration or thorough transition. International Journal of Sustaina-ble Energy Planning and Management 5: 57–68. Wealer, Ben and Bauer, Simon and Göke, Leonard and von Hirschhausen, Christian and Kemfert, Claudia, Economics of Nuclear Power Plant Investment: Monte Carlo Simulations of Generation III/III+ Investment Projects (No-vember 2019). DIW Berlin Discussion Paper No. 1833, SSRN https://ssrn.com/abstract=3494247 or http://dx.doi.org/10.2139/ssrn.3494247	Noted	Aviel Verbruggen	University of Antwerp	Belgium
29923	128	1	203	6	Additional references; In our comments we have added several references that was not currently referred in your chapter. Please include them as appropriate as references to the chapter. For your convenience, here is a shortlist of which we have linked to in previous comments - Prairie et al (2018), Bakken et al (2016), Mohdal et al (2013), Hayes et al (2019), EU commision 2020 - Mitigation library, EUs taxonomy of sustainable finance. McManamay 2016 and IHA sustainability protocol,	Noted	Government of Norway	Norwegian Environment Agency	Norway

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
62021	131	32	131	32	Complete the reference "Baker, 2020: Revision 1 August 2020." to include title etc.	Accepted. - This should be corrected	Esa Vakkilainen	LUT University, Lappeenranta	Finland
62023	132	1	132	1	Typo: change "Bank, W., Ecofys, and V. Economics, State and Trends of Carbon Pricing 2017. World Bank Other" to "World Bank, Ecofys, and Vivid Economics, 2017: State and Trends of Carbon Pricing 2017. World Bank Other"	Accepted-I have adjusted the author list and put it in place .	Esa Vakkilainen	LUT University, Lappeenranta	Finland
78725	136	1	136	3	the first author is Breyer and not Bogdanov - please check and correct	Accepted.	Christian Breyer	LUT University	Finland
78727	137	11	137	12	parts of the bibliography are missing - here the link for checks: https://onlinelibrary.wiley.com/doi/full/10.1002/pip.3114	Accepted.	Christian Breyer	LUT University	Finland
62025	142	28	142	28	Typo: change "D. Westlén, 2018: Nuclear power and high sea water temperatures. 45–47 pp." to "Westlén, D., 2018: Nuclear power and high sea water temperatures. 45–47 pp."	Accepted-I have adjusted the author list and put it in place .	Esa Vakkilainen	LUT University, Lappeenranta	Finland
79791	143	14	143	17	The reference Davis, S. J., and Coauthors, 2018a: Net-zero emissions energy systems. Science (80-.)., 360, eaas9793, https://doi.org/10.1126/science.aas9793."" is placed twice in te reference list	Accepted.	Constantinos Psomopoulos	University of West Attica, Department of Electrical and Electronics Engineering	Greece
62027	145	8	145	10	Typo: change "Dmitrii, Bogdanov, Christian, and Breyer, 2016: " to "Bogdanov, D., and C. Breyer, 2016: "	Accepted.	Esa Vakkilainen	LUT University, Lappeenranta	Finland
78717	145	8	145	10	the first and last names of authors are mixed up	Accepted-I have adjusted the author list and put it in place .	Christian Breyer	LUT University	Finland
78729	149	4	149	6	list of authors is not fully correct, please re-check	Accepted-I have revised the author list.	Christian Breyer	LUT University	Finland
84579	149	6	149	7	Please add after "...contexts.": "Karlsson, M., Alfredsson E. & Westling N. (2020) Climate policy co-benefits: a review, Climate Policy 20, 292-316. DOI: 10.1080/14693062.2020.1724070".	Taken into account-According to Comment No. 15, it has been inserted.	Mikael Karlsson	KTH Royal Institute of Technology	Sweden
4885	155	41	155	44	The Reference should be: Saunders, H., Roy, J., Azevedo, I. Chakravarty, D. Dasgupta, S., de la rue du Can, S., Druckman, A., Fouquet, R., Grubb, M., Lin, B.Q., Lowe, R., Madlener, R., McCoy, D., Mundaca, L., Oreszczyn, T., Sorrell, S., Stern, D., Tanaka, K., Wei, T., 2021: Energy Efficiency: What has it Delivered in the Last 40 years? Ann. Rev. Environment and Resources (submitted), Working paper: https://www.fcn.eonerc.rwth-aachen.de/cms/E-ON-ERC-FCN/Forschung/~emvl/Arbeitspapiere/lidx/1/	Accepted.	Harry Saunders	Carnegie Insitution for Science, Global Ecology Group, Stanford, USA	United States of America
84571	162	5	162	6	Please insert the following reference: "Karlsson, M., Alfredsson E. & Westling N. (2020) Climate policy co-benefits: a review, Climate Policy 20, 292-316. DOI: 10.1080/14693062.2020.1724070".	Accepted-I have changed the format, "Karlsson, M., Alfredsson E. & Westling N. (2020) Climate policy co-benefits: a review, Climate Policy 20, 292-316. DOI: 10.1080/14693062.2020.1724070"to "Karlsson, M., E. Alfredsson, N. Westling, 2020: Climate policy co-benefits: a review. Climate Policy, 20, 292-316, https://doi.org/10.1080/14693062.2020.1724070". In addition, I put it in the right place, after"Karlin, B., J. F. Zinger, and R. Ford, 2015: The effects of feedback on energy conservation: A meta-analysis. Psychol. Bull., 141, 1205–1227, https://doi.org/10.1037/a0039650."	Mikael Karlsson	KTH Royal Institute of Technology	Sweden
78719	164	4	164	6	the bibliography is not complete, as the article number and DOI is missing	Accepted.	Christian Breyer	LUT University	Finland
62029	170	34	170	35	Typo: change "Mai, T., and Et al, 2014: Renewable Electricity Futures for the United States. IEEE Trans. susta, 5, 372–378, https://doi.org/10.2172/1219711." to "Mai, T., and coauthors, 2014: Renewable Electricity Futures for the United States. IEEE Trans. susta, 5, 372–378, https://doi.org/10.2172/1219711."	Accepted.	Esa Vakkilainen	LUT University, Lappeenranta	Finland

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
62031	178	10	178	10	Typo: change "of energy efficiency, O., renewable energy, O. energy efficiency, and R. energy, 2018: Hydrogen" to "Office of energy efficiency, Office of renewable energy, Office energy efficiency, and Renewable energy, 2018: Hydrogen"	Accepted.	Esa Vakkilainen	LUT University, Lappeenranta	Finland
62033	178	12	178	12	Typo: change "of Transport, D., 2017: £23 million boost for hydrogen-powered vehicles and infrastructure." to "Department of Transport, 2017: £23 million boost for hydrogen-powered vehicles and infrastructure."	Accepted.	Esa Vakkilainen	LUT University, Lappeenranta	Finland
85601	191	1	191	19	First author name is missing.	Accepted-I have added the first author of these references.	San Win	Environmental Conservation Department, Ministry of Natural Resources and Environmental Conservation	Myanmar
37557	841	4	841	5	A CAGR decline of 2.2% - 3.3% over 30 years cannot get to even near zero, unless there is a huge offset (e.g,. DAC or LULC). If you do simple math, these correspond to leaving 51% and 37% after 30 years. A **LINEAR** decline per year in absolute terms might bring us to 33% to 0% over 30 years, but that needs to be clarified. The 2000-2018 CO2 emissions growth of over 2% are a CAGR. Please check?	Taken into account. We have revised the way we represent changes over time	Government of India	Ministry of Environment, Forests and Climate Change	India
37559	847	2	847	2	Change the RHS of Figure 6.2 into percentage change instead of absolute	Accepted	Government of India	Ministry of Environment, Forests and Climate Change	India
37561	848	12	848	14	To say that there is CO2 emissions reductions only in N. America and Europe without mentioning they reduced from a very high base per capita is misleading.	Rejected. There is plenty of information on relative contributions to emissions throughout the report. Here we are just discussing the Kaya identify breakdown. The previous figure already notes the differential contributions to global emissions among regions.	Government of India	Ministry of Environment, Forests and Climate Change	India
37563	853	5	853	6	Most of global coal trends are explained by China, which uses half the world's coal. Chinese policies for cleaner air, and import choices and a move to gas explain much of the ups versus downs. A global generalization is misleading	Taken into account. We have highlighted both the contributions of different regions to coal as well as the fact that other priorities have driven coal actions.	Government of India	Ministry of Environment, Forests and Climate Change	India
37565	853	7	853	8	modify sentence: Coal use is decreasing in the U.S, the European Union, and many other OECD countries, not just because of the rise of RE but also due to the rise of natural gas.	Taken into account. We note that old coal fleets have been replaced have by gas and half by renewables in the U.S.	Government of India	Ministry of Environment, Forests and Climate Change	India
37567	853	20	853	22	The statement that the EU mostly replaced coal with RE is partly misleading as countries like the UK shifted over to gas well before the period in question.	Noted. The discussion here is over the last five or so years. There are many different trends that could be discussed if we go back many years before that.	Government of India	Ministry of Environment, Forests and Climate Change	India

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
37569	853	34	853	34	Add 2 paragraphs after line 34: Many developing regions, especially India, have extensive coal use but this needs to be placed into proper context. For starters, China dominates global coal use, using half the world's coal. A measurable fraction of coal use is for metallurgical or coking coal, for steel production, and countries with a lower level of infrastructure and housing buildout have fewer choices to use secondary steel and recycling processes. The lowered use of coal in many developed regions still leaves them with higher per capita coal use, often multiple times higher that India's as of 2019. This is even after ignoring the area under the curve for cumulative coal use and attendant emissions. If we normalize the per capita tons of coal consumed by coal quality or energy content, a proxy for carbon emissions, we find that India's 2019 per capita coal consumption was close to half the world average (Tongia and Sehgal, 2020, Table 1.1). If we further examine share of coal in total energy use, then countries that appear green due to low coal use suddenly look less green when we factor in the high use of other fossil fuels beyond coal. Full reference: R. Tongia and A. Sehgal, editors, Future of Coal in India: Smooth Transition or Bumpy Road Ahead?", Notion Press and Brookings India, September 2020. The table is visible online in a blog: https://csep.org/blog/future-of-coal-in-india-smooth-transition-or-bumpy-road-ahead/	Rejected. These paragraphs are too detailed for the purpose of this section, but we have tried to include some of the key themes in the discussion. More thorough discussion of historical trends can be found in Chapter 2.	Government of India	Ministry of Environment, Forests and Climate Change	India
37571	855	31	853	32	Change sentence to: China and India are the largest coal consumers on a national level, despite not being the highest consumers per capita, and they have no committed plans to phase out coal. Their coal usage isn't similar, neither in scale, nor timeframes; China's coal capacity levels are multiple times higher per capita and preceded India's growth by a decade.	Taken into Account. The paragraph has been substatially revised, and the sentence is no longer there.	Government of India	Ministry of Environment, Forests and Climate Change	India
37573	858	6	858	7	Battery pack costs shown are WAY too low. BNEF has some of the most widely accepted prices, and their figure for 2019 was $156/kWh (and not $56!!). See reference: Bloomberg BNEF 2019 Lithium-Ion Price Survey	Taken into account. The paragraph has been revised and the number is no longer there.	Government of India	Ministry of Environment, Forests and Climate Change	India
37575	869	33	871	37	The entire section on hydropower (6.4.2.3) doesn't sufficiently mention the benefits of hydropower in a high RE world, where increased flexibility and ramping are both key requirements. Hydro could even be a storage option for RE with pumped hydro, but even without pumped hydro mode, its timing of use often provides measurable control for generation timings.	Taken into account. The whole section on hydropower has been revised and these two benefits of hydropower are mentioned.	Government of India	Ministry of Environment, Forests and Climate Change	India
37577	876	9	876	9	Table 6.2 - should clarify if the last column is incremental or net avoided cost for CO2, because in some cases (oil and gas) the avoided cost is lower than the capture cost, suggesting there must be some value for the CO2 (maybe enhanced oil recovery?)	This is the incremental avoided cost.	Government of India	Ministry of Environment, Forests and Climate Change	India
37579	941	7	941	7	Box 6.9, check if this is an error. For Latin America and caribbiean, the Full economy net-zero is shown BEFORE electricity net-zero.	Noted and checked. Due to activities in AFOLU primarily, net zero economy is first, whilst residual emissions remain from the energy system.	Government of India	Ministry of Environment, Forests and Climate Change	India

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
37581	950	3	950	3	Add few sentences after "The lifetime of these plants is also high i.e. 40-50 years, creating long lasting risks to climate goals (Erickson and Tempest 2015).": On the other hand, especially given higher interest rates in many developing regions, the accounting life is often much lower. For example, in accounting terms India plans for coal plants to only operate for 25 years. There are numerous examples of utilities and countries stopping the use of still functional power plants because a cheaper alternative emerged, which leaves no stranded asset cost.	Noted. We do not intend to call out India in this general statement about lock in. Stranded asets are discussed in more detail in box 6-13. Retiring a technology before its useful life for any reasons has an economic impact, and that is what we are noting here. Indeed, the implication of climate policy is that fossil plants will be made less competitive, which will potentially leave them stranded. Stranding can arise becuase the fossil plants become more expensive or because alternatives become cheapter.	Government of India	Ministry of Environment, Forests and Climate Change	India
37583	950	30	951	2	This paragraph is misleading. It suggests irrationality on the part of developing regions. Many of them are adding high amounts of RE, but yet still add coal or gas capacity as that is the cheapest visible option to meet firm demand. As an example, India added extensive coal-based capacity only through FY15-16. After that, it's coal growth has been miniscule if not negative in some years (with some decommissioning) - almost all the new growth just now is from RE.	Noted. The implication of this paragraph is that the need to reduce fossil fuels for climate and for other reasons, this is not sufficient to reduce fossil use, for just the reasons noted here. Earlier paragraphs explicitly noted the increased deployment of renewable resources.	Government of India	Ministry of Environment, Forests and Climate Change	India
8895	?	?	?	?	Having read Chapter 16, I think there may be opportunity for some more details on the role of digitalisation. There is a range of digital technologies (asset performance management, DER managament, mobile workforce management) that exist and can support the net zero transition. One good source on this topic is V. Sivaram, ed., Digital Decarbonization: Promoting Digital Innovations to Advance Clean Energy Systems, Council on Foreign Relations, June 2018.	Rejected. Comment not specific	Seth Dunn	ServiceMax	United States of America
2879					The report should put more emphasis on mitigation options that are affordable to the low-income population and specifically options that have synergies with the no poverty SDG	Noted. We cover linkages to SDGs in 6.7, and we explore linkages to other societal priorities for every mitigation option in 6.4.	Leonardo Barreto	Head of center "EU&International"	Austria
2907					social innovation can facilitate the adoption of renewable or other low-carbon technologies by society. Examples of social innovations are energy cooperatives, energy "prosumers" consuming and producing energy and new participative forms of decision making such as citizen assemblies. They enable new business models and governance arrangements and can contribute to making energy more sustainable and affordable (see e.g. European Commission, 2013: Guide to Social Innovation. Regional and Urban Policy. February, 2013. https://ec.europa.eu/eip/ageing/library/guide-social-innovation_en or Wittmayer, J., de Geus, T., et al. 2020: Beyond instrumentalism: Broadening the understanding of social innovation in socio-technical energy systems, Energy Research & Social Science, ISSN: 2214-6296, Vol: 70, Page: 101689).	Noted. We do not see how this influences the chapter.	Leonardo Barreto	Head of center "EU&International"	Austria
9497					Just Transition is mentioned here and there across Chapter 6, but not handled in an integrated way anywhere that I could see. I suggest you consider a more consolidated text on JT in 6.7 to handle it more effectively in terms of key messages.	Rejected. Space constraints have limited our ability to do this, but we have tried to pull out just transition issues in the context fo the coal phaseout box and in the fossil transition portion of the chapter.	Patrick Devine-Wright	University of Exeter	United Kingdom (of Great Britain and Northern Ireland)

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
9499					Table 6.1: "Public acceptance (12/13): extent to which the public supports the option and will change their behavior accordingly". This theme is consistent with the bulk of the text on public acceptance in the chapter in having a predominant focus on technology adoption as a behavioural outcome. While this works for domestic solar PV or an EV, it is less useful when people live near a proposed wind farm or transmission line. The focus on public acceptance could be broadened to encompass both of these contexts of energy transition. This is not just a point about this Table, but applies across the text of Chapter 6.	Noted, that is exactly what we did. Acceptance reflects public support, including support for siting wind farms for example	Patrick Devine-Wright	University of Exeter	United Kingdom (of Great Britain and Northern Ireland)
9501					The highly cited framework of social acceptance proposed by Wustenhagen et al (2007) and extended in the last decade defines acceptability in multiple dimensions (markets, political and community) that are interdependent and are not solely about public acceptance. These important points of definition, multi-dimensionality and interdependence could be more clearly reflected in the contents of Table 6.1 and the chapter more generally. See also more recent studies by Batel (https://doi.org/10.1016/j.erss.2020.101544), Wolsink (https://doi.org/10.1016/j.erss.2018.07.034) and Devine-Wright (http://dx.doi.org/10.1016/j.enpol.2017.04.020).	Noted, we do consider multiple aspects of acceptance, including public acceptance under socio-cultural feasibility, and politcal acceptance under Institutional feasibility	Patrick Devine-Wright	University of Exeter	United Kingdom (of Great Britain and Northern Ireland)
9791					There are many form of energies such as electric, mechanical, magnetic, chemical, ionization, nuclear, thermal, wave, potential, kinetic energy; I believe, the authors should include an introductory section where they will highlight all form of energies and then discuss more on the ones that carry significant climate change impact. This comment applies to the executive summary of the chapter 6 as well.	Rejected. Although it would be nice to provide such a primer, we do not have sufficient space given other priorities.	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
9797					please add reference to Figure 6.4, 6.5	Accepted. Ref added	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
9815					please add a list of nomenclature in every chapter	Noted. The report has not been designed this way.	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
10071					There are abundant discussions on net-zero emission energy system, however “distributed energy system” topic may still relevant for developing countries and emerging economies that has interest to transform their energy system. Therefore, more discussions on that topic is suggested.	Noted. While it's true that we don't discuss distributed systems in specific, we do discuss the value of solar, batteries, other forms of storage, and other approaches to provide distributed services. We also discuss the valuae of distributed systems for resilience in Box 6.6.	Government of Indonesia	Ministry of Environment and Forestry	Indonesia
25015					Could mention advances in other battery technologies in addition to LIB, e.g. Liquid metal or graphene	Noted. We believe we have a strong assessment of batteries and other storage options given space constraints and other priorites.	Bassam AbuHijleh	The British University in Dubai	United Arab Emirates
25017					Resilience of distributed generation and microgrids associated with RE is important on disaster situations	Taken into Account. We now have a box on resilience, and it includes mention of micro grids.	Bassam AbuHijleh	The British University in Dubai	United Arab Emirates
25019					Promotion of DC power equipment also helps reduce electricity loses due to convertors & invertors; could be mentioned as a recommendation.	This DC technologies for electricity transmission are investigated in detail in section 6.4.5	Bassam AbuHijleh	The British University in Dubai	United Arab Emirates
27707					Replace "Fossil fuel CO2 emissions" with "energy related CO2 emissions".	Rejected. Energy system CO2 emissions come almost entirely from burning fossil fuels.	Eleni Kaditi	Organization of the Petroleum Exporting Countries, OPEC	Austria
27761					The Chapter has no dedicated section on knowledge gaps, contrary to the other chapters.	Noted. There is no standard for whether such a section should be included.	Eleni Kaditi	Organization of the Petroleum Exporting Countries, OPEC	Austria

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
37119					Average life cycle GHG emissions of solar PV is more than twice of as that of nuclear. This must be mentioned.	Rejected. We have chosen not to focus on near-term lifecycle emissions and instead to focus on long-term pathways to low emissions, over which time lifecycle emissions will change dramatically.	Arun kumar Nayak	Bhabha Atomic Research Centre Trombay Mumbai	India
55891					There are three different sections that cover hydrogen: Section 6.4.5.1, parts of Section 6.6.2.4, and Box 6.7. Each section covers some of the same ideas, mentioning costs and barriers, but it could be a better resource for readers if all of that information was in one place and synchronized so that there isn't a difference in data being cited and the reader doesn't have to jump around the chapter to understand everything that it is saying about hydrogen.	Noted. This is a good point. We are loathe to consolidate, however, because hydrogen plays various roles in the energy system and therefore needs to be addressed in various places. In addition, we address all technological options in 6.4, but then we discuss how they might be deployed in the future in 6.6 and 6.7.	Government of United States of America	U.S. Department of State	United States of America
55893					Note somewhere, in cases where modeled outcomes that concern BECCS are presented, models assume biomass combustion is carbon neutral, as it is a major driver in high BECCS adoption at higher reduction volumes.	Taken into account. We discuss the lifecycle emissions of bioenergy and BECCS in Section 6.4	Government of United States of America	U.S. Department of State	United States of America
55895					The timescale of the content in this chapter is centered on 2050 with some additional flexibility for subsequent decades depending on the contextual target (1.5 or 2°C) and uncertainty in the resource material. While this focus has a useful purpose, it overlooks the value of more immediate benchmarks that could be used to measure progress towards the stated goals outlined for 2050 or beyond. IPCC should consider including these intermediate benchmarks in this chapter in future ARs.	Noted. We have included a number of figures that show 2030, and we have also included more references to 2030 in the ES.	Government of United States of America	U.S. Department of State	United States of America
55897					Many figures are incomplete (e.g., missing axes labels).	Accepted	Government of United States of America	U.S. Department of State	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
55899					CHP is a near-term -- and depending on the fuel and industry -- a longer term technology solution in applications where there is a concurrent thermal and electrical energy need. CHP data in China, Europe, and the U.S. show it's use in the pulp and paper, manufacturing, food processing, chemical refining, and the metals industries. There are several technology choices that can support lowering emissions. They consist of CHP systems that use renewable fuels, and others that offer load flexibility and improve site resiliency. Though it's a well-known technology, there is very little data that provide a deeper analysis because of the analytical challenge posed. These challenges are a direct outcome of the fact that it is a highly variable technology and is uniquely developed at each site. However, there are studies published by NREL recently that examine the role of CHP in California and in the U.S. that elucidate CHP's role in the context of other available options. Studies have also been done in China, Europe, and U.K. to place it's role into context. Some references are provided below: MODELING THE IMPACT OF FLEXIBLE CHP ON THE FUTURE ELECTRIC GRID IN CALIFORNIA, August 2020, prepared by the Oak Ridge National Laboratory. Low Carbon Grid Study:Analysis of a 50% Emission Reduction in California, Technical Report NREL/TP-6A20-64884, January 2016 Accelerating the US Clean Energy Transformation: Challenges and Solutions by Sector, Charles F. Kutscher, Jeffrey S. Logan, Timothy C. Coburn, University of Colorado Boulder, December 2020 Managing energy infrastructure to decarbonize industrial parks in China, Nature, Yang Guo, Jinping Tian, Lyujun Chen. December 2020 Wang, H., Chen, W., Zhang, H. et al. Modeling of power sector decarbonization in China: comparisons of early and delayed mitigation towards 2-degree target. Climatic Change 162, 1843-1856 (2020). https://doi.org/10.1007/s10584-019-02485-8 Victoria, M., Zhu, K., Brown, T. et al. Early decarbonisation of the European energy system pays off. Nat Commun 11, 6223 (2020). https://doi.org/10.1038/s41467-020-20015-4	Noted. Thank you for this information. Combined heat and power in industrial applications is is being handled in the Industry chapter.	Government of United States of America	U.S. Department of State	United States of America
55901					Ensure that a consistent terminology is used to describe combined heat and power and cogeneration. There is currently no definition provided and the words used indiscriminantly. The U.S. EPA and DOE maintain consistent language and the DOE definition calls out the linkage. It can be found at https://betterbuildingssolutioncenter.energy.gov/chp/basics and shared below: ""Combined heat and power (CHP), also known as cogeneration, is: The concurrent production of electricity or mechanical power and useful thermal energy (heating and/or cooling) from a single source of energy. A type of distributed generation, which, unlike central station generation, is located at or near the point of consumption. A suite of technologies that can use a variety of fuels to generate electricity or power at the point of use, allowing the heat that would normally be lost in the power generation process to be recovered to provide needed heating and/or cooling. It is reasonable to expect CHP applications to operate at 65-75% efficiency, a large improvement over the national average of ~50% for these services when separately provided.""	Noted. We have tried to be consistent with standard definitions when we mention combined heat and power.	Government of United States of America	U.S. Department of State	United States of America

Comment Id	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
60513					Carbon Capture and Utilisation (CCU) is now considered as a solution to mitigate climate change in the IPCC AR6 WGIII SOD, however its definition and several key messages need to be refined to reflect the literature. CCUS is barely used anymore, but CCU and CCS are still mixed sometimes, especially when discussing the barriers and needs of CCS, which does not do good to CCU as the barriers and needs are not the same. CCU technologies are available now and offer solutions to reduce net CO2 emissions with an estimated potential impact of gigatons equivalent CO2 emissions. Indeed, CCU technologies have the potential to utilize up to 8 Gt of CO2 per year by 2050 (GCI, 2016, Hepburn et al., 2019), this is equivalent to approximately 15% of current global CO2 emissions. Moreover, When CO2 is captured directly and stored permanently via mineralization into building materials, CCU can also create negative emissions (e.g.Di Maria et al., 2020, Ostovari et al., 2020). Unlike other options, CCU technologies provide drop-in solutions which can be implemented without requiring significant modification of existing production, distribution and use infrastructure (e.g. Ampelli et al., 2015, Hepburn et al., 2019). Another important asset of CCU technologies is the utilisation of CO2 as carbon feedstock to replace fossil resources (e.g. Sternberg et al., 2017, Daggash et al., 2018, Kätelhön, et al., 2019, Thonemann, 2019) and support the development of a circular economy, e.g. when CO2 is used together with industrial wastes to create materials (e.g. Di Maria et al., 2020, Ostavari et al., 2020). CCU technologies have the potential to provide solutions to hard-to-abate sectors, but also to generate revenues through producing marketable products (e.g. Hepburn et al., 2019, Zhu, 2019). Because of their lack of granularity, Integrated Assessment Models (IAM's) have yet failed in simulating the complexity of the different CCU options to realize net zero or negative CO2 emissions (e.g. Detz and Zwaan, 2019). Consequently, no exhaustive quantification exists today on the climate mitigation potential of this large panel of technologies. However, their key role should be considered as one building block in a	Accepted. We have tried to use clearer language to distinguish between CCU and CCS.	Célia Sapart	Université Libre de Bruxelles / CO2 Value Europe	Belgium
62035					Typo: change "" to ""	Noted. There is no page number.	Esa Vakkilainen	LUT University, Lappeenranta	Finland
62117			25	29	The sentence about hybrid PV-battery systems is unclear to wrong: Modern CSP plants are inherently dispatchable and even with decreasing battery prices continue to be the cheapest option for night-time generation for more than 4 hours, thus making CSP plants a good complement for PV rich power systems to power the evening and night loads as well as providing (together with PV)cheap baseload solar power for industrial applications like smelting or hydrolysis .See for example Schöniger et al 2021: https://www.tandfonline.com/doi/full/10.1080/15567249.2020.1843565 and www.csp.guru	Reject. The following sentence clearly makes the point the reviewer is making abut the value of longer term storage with CSP.	richard thonig	IASS Potsdam	Germany

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75679					Fig.6.1 – top assumes about 50% of losses in power plants, but bottom one only 10% - this is technical nonsense, because bottom one also works with electricity only and losses during energy transition, conversion (low to high voltage for losses reduction during transmission and back to low one for using, conversion DC to AC and so on) The bottom too idealized with neglection of important physical limitation for “preferred solar and wind”. Out of any logic, the contribution of nuclear is presented reduced from 30 EJ to 1.6 EJ – why? there is no reason, because in 2060 so many units will be in their operating live-time (regular or extended). Overall consumption for 2018 is 406 EJ, for 2060 is expected only 370.9 EJ, about 10% less, but there is trend of growing consumption and there is serious assumption of other increase due to higher consumption in the parts of the word with very limited access to electricity. The access to energy is a key factor for reduction of potential risk of wars because people with sufficient access to power sources have less needs to reach sources of their neighbors. As an evidence - 860 million peoples were without access to electricity in 2018 p.6-15 l.11-12.	Noted-. Losses are not only for nuclear but for all electricity system. Nevertheless . Losses are revised. Issue of nuclear will be checked	Jiri Duspiva	Czech Nuclear Society	Czech Republic
75681					This chapter absolutely missed any comparative information concerning their impacts to the environment including all externalities. It means for example for solar (photovoltaic) sources – to include the production of all kinds of emission due to their production (not only CO2), transport and also due their decommissioning. The data included in the comparison contain only those emissions due to operation and such approach is really deceptive. It is important also, for each of sources, to compare the overall production of energy with the overall consumption of energy for whole life cycle (including also storage of energy in case of sources with unstable and unpredictable production – like batteries for solar or wind plants, or production in backup sources). If this ratio is coming close to 1 the appropriateness of such source is very questionable and if it is less than 1, such source must be rejected.	Taken into Account. The feasibility framework in 6.4 is focused explicitly on these issues.	Jiri Duspiva	Czech Nuclear Society	Czech Republic

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83757					Carbon Capture and Utilisation (CCU) is now considered as a solution to mitigate climate change in the IPCC AR6 WGIII SOD, however its definition and several key messages need to be refined to reflect the literature. CCUS is barely used anymore, but CCU and CCS are still mixed sometimes, especially when discussing the barriers and needs of CCS, which does not do good to CCU as the barriers and needs are not the same. CCU technologies are available now and offer solutions to reduce net CO2 emissions with an estimated potential impact of gigatons equivalent CO2 emissions. Indeed, CCU technologies have the potential to utilize up to 8 Gt of CO2 per year by 2050 (GCI, 2016, Hepburn et al., 2019), this is equivalent to approximately 15% of current global CO2 emissions. Moreover, When CO2 is captured directly and stored permanently via mineralization into building materials, CCU can also create negative emissions (e.g.Di Maria et al., 2020, Ostovari et al., 2020). Unlike other options, CCU technologies provide drop-in solutions which can be implemented without requiring significant modification of existing production, distribution and use infrastructure (e.g. Ampelli et al., 2015, Hepburn et al., 2019). Another important asset of CCU technologies is the utilisation of CO2 as carbon feedstock to replace fossil resources (e.g. Sternberg et al., 2017, Daggash et al., 2018, Kätelhön, et al., 2019, Thonemann, 2019) and support the development of a circular economy, e.g. when CO2 is used together with industrial wastes to create materials (e.g. Di Maria et al., 2020, Ostavari et al., 2020). CCU technologies have the potential to provide solutions to hard-to-abate sectors, but also to generate revenues through producing marketable products (e.g. Hepburn et al., 2019, Zhu, 2019). Because of their lack of granularity, Integrated Assessment Models (IAM's) have yet failed in simulating the complexity of the different CCU options to realize net zero or negative CO2 emissions (e.g. Detz and Zwaan, 2019). Consequently, no exhaustive quantification exists today on the climate mitigation potential of this large panel of technologies. However, their key role should be considered as one building block in a	Accepted. We have tried to use clearer language to distinguish between CCU and CCS.	Christian Breyer	LUT University	Finland
86073					Political constraints to carbon pricing should be discussed consistently with what done in chapter 5 (see e.g. Carattini, Carvalho, and Fankhauser WIREs CC 2019; Klenert et al. NCC 2019 as reviews).	Noted. we have only limited space so that we cannot go into detail regarding this issue in the revised version.	Carattini Stefano	Georgia State University	United States of America
86075					It is surprising that there is no mention of social contagion in the adoption of clean technologies (see Carattini, Levin, Tavoni REEP 2019 for a review) and in particular for hybrid cars (Narayan and Nair 2013; Heutel and Muehlegger 2015) and solar PV (e.g. Bollinger and Gillingham 2012; Graziano and Gillingham 2016; Rode and Weber JEEM 2016; Baranzini, Carattini, and Péclat GRI WP 2017). It is also surprising that there is no discussion of visibility (and lack thereof), see Carattini, Levin, Tavoni (REEP 2019) and Carattini, Gosnell, Tavoni (World Development 2020) and on how to bring non-normative behaviors to normative (e.g. Spencer, Carattini, Howarth RBE 2019).	Noted. We have covered behavior issues at severlal points in the chapter.	Carattini Stefano	Georgia State University	United States of America

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86995					Box 6.1 We should consider including in Box 6.1 and/or other subsections in Chapter 6: 1. An approximate scale of "vast Africa" - which is not well covered in literature and presents challenges in selecting energy systems and financing mechanisms over that vast terrain: "The continent is huge in scale – around the size of the United States, China, India and Europe combined" from Africa Energy Outlook 2014 - World Energy Outlook Special Report page 20 https://webstore.iea.org/download/direct/416?fileName=WEO2014_AfricaEnergyOutlook.pdf 2. "Africa needs a significant scale-up in electricity sector investment in generation and grids, for which it currently ranks among the lowest in the world. Despite being home to 17% of the world's population, Africa currently accounts for just 4% of global power supply investment. Achieving reliable electricity supply for all would require an almost fourfold increase, to around $120 billion a year through 2040. Around half of that amount would be needed for networks". page 16, IEA Africa Energy Outlook 2019) We have covered financing costs for clean cooking? We should consider reflecting the $120bn a year through 2040 for consistency with the figures in Chapter 15 Investment and Finance section 15.6.7'development of local capital markets 3. We have covered Solar Photovoltaics/Inorganic on land. Other solar options we should consider including - the use of Africa's existing hydropower facilities: access rights and grid connection certainty are often easier to obtain than land related permits and rights notwithstanding issues around security of tenure https://www.pv-magazine.com/2021/02/05/the-untapped-potential-of-floating-pv-in-africa/ 4. We could also consider reflecting the potential in organic photovoltaics/next generation photovoltaics	Rejected. No space to cover Africa here. However Africa issues are being addressed throughout the chapter see for instance box 61 and other chapters,	Nokuthula Dube	Africa Energy and Finance	United Kingdom (of Great Britain and Northern Ireland)