Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
1549	0	0	0	0	The topic of energy poverty in developed countries may receive more attention in this chapter. This is a growing problem for lower-income target groups in many Western countries. It can be a strong barrier for GHG reduction in these countries. Furthermore, it is an issue of growing inequality in the world. Both are UN Development goals. Literature: Tardy & Lee (2019). Building related energy poverty in developed countries – Past, present, and future from a Canadian perspective. Energy and Buildings, Volume 194, 1 July 2019, Pages 46-61. https://www.sciencedirect.com/science/article/pii/S037877881832485X?dgcid=rss_sd_all	Rejected. Space constraints have limited our ability to focus on this issue, and it may be covered more effectively in other chapters.	Paul Vethman	PBL Netherlands Environmental Assessment Agency	Netherlands
11519	0	0	0	0	It is good to see that this chapter has a section on “The Costs and Benefits of Energy System Transitions in the Context of Sustainable Development”. However, there is lack of facts in monetary values of costs and benefits of various energy system transitions. Addition of these examples would be useful for investors, businesses, households or decision makers in motivations or transitions to low carbon economy or society. This chapter can provide some examples of costs and benefits (in monetary value) of energy system decarbonisation.	Accepted	Rawshan Ara Begum	Universiti kebangsaan Malaysia (UKM)	Malaysia
28879	0	0	0	0	Most of Figure is placed without mentioned on the paragraph. So, often I feel lost about what is the relation between the figure and the paragraph?	Accepted	Marissa Malahayati	National Institute for Environmental Studies	Japan
29089	0	0	0	0	The approved outline for Ch 6 includes a bullet on fugitive and non-CO2 emissions. Methane emissions are briefly mentioned but please see if this needs a subsection in SOD	Taken into account. We have addressed fugitive emissions in Section 6.3 but do not feel that it requires a special section.	Minal Pathak	Ahmedabad University	India
39069	0	0	0	0	SPLIT OF CCUS (COMMENT 1/6): In the report, the term CCUS (Carbon Capture Utilisation and Storage) is broadly used but not clearly defined and in most cases, 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, 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 find below the key differences between CCS and CCU:In the case of CCS, large quantities of CO2 are captured from flue gas or from ambient air, then transported to storage locations and buried in geological settings. The storage is meant to be permanent, i.e., for more than a thousand years (e.g. Metz et al., 2005, IEA, 2013). In the case of CCU, CO2 can be captured similarly, but it is subsequently converted into valuable products (e.g. building materials, chemicals, synthetic fuels) (Styring et al., 2011; von der Assen et al., 2013, Kätelhön et al., 2019). The duration of the CO2 storage into a product strongly varies from days to centuries according to the applications. While the environmental assessment of CCS projects may be relatively straight forward, it is not the case for CCU technologies. Indeed, CCU projects should not be assessed only with respect to the amounts of CO2 that can be used but rather it is essential to determine the life cycle of the CO2-based product generated (e.g. Bruhn et al., 2016, Nocito et 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, 2019b, 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.	Taken into account. We cover both CCS and CCU and comment on both of their characteristics in Section 6.4 and discuss the role of CCUS throughout the chapter. All of these have been improved since the FOD. But space does not permit us to have separate sections on CCU and CCS.	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
39069	0	0	0	0	SPLIT OF CCUS (COMMENT 1/6), continued: 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. The potential applications of CCU are diverse, ranging from using CO2 in greenhouses and farming to conversion of CO2 into fuels, chemicals, polymers and building materials. 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. There are also many new CO2-utilization technologies at various stages of development and commercialization. These technologies have the potential to provide opportunities for emission savings for power and other industrial sectors by substituting fossil-fuel raw materials, increasing efficiency and using renewable energy, and generating revenues through producing marketable products (e.g. Hepburn et al., 2019, Zhu, 2019). When the deployment of CCS can be compromised by its costs, CCU can offset some of the cost of CCS by providing additional revenue streams that create a more compelling business case. Also, CCU can be applied in closed-loop concepts (e.g. capturing CO2, producing CH4 through hydrogenation, using CH4 for energy purposes, capturing the emitted CO2 and repeating the cycle) or in permanent CO2 sequestration in building materials (e.g. through mineralization) thereby reducing the amounts that CCS needs to handle (Bruhn et al., 2016, Daggash et al., 2018, Koytsoumpa et al., 2018).		Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
39071	0	0	0	0	SPLIT of CCUS(COMMENT 2/6): CCS versus CCU in the energy system transition: CCS is a relatively old concept that has been proposed at first as a way to reduce the climate impact of continued fossil power generation at increased energy costs (Metz et al., 2005, IPCC-SR-1.5, 2018), but this strategy counteracts the deployment of renewables and shift the environmental costs of today's emissions onto future generations. Hence, large-scale CCS deployment does not represent a step towards a shift of the energy system away from fossil resources (e.g. ZERO, 2015, Bruhn et al., 2016). Current trends worldwide indicate that energy systems in this century will increasingly be based on electricity, mainly due to high technical efficiencies, comparably lower costs and the availability of prospective power-to-X technologies. These power-to-X technologies include sustainable or nonavoidable CCU (Farfan et al., 2019, Ram et al., 2019). Excess renewable energy, generated when the demands for energy are low, could potentially provide an inexpensive or even negatively priced energy supply for CO2 conversion to products. Energy storage technologies could harness excess generation that would otherwise be curtailed and make it available for use in CCU. Transport technologies are also expected to play an important role due to the likelihood that conversion technologies and sources of raw material will be in different locations (Jarvis and Samsatli, 2018). Also and in contrast with CCS, CCU technologies aim to replace fossil resources and thus they support a transformation towards renewables and extend it to industries outside the energy sector such as transport and materials (e.g. Klankermayer and Leitner, 2015). CCU as the power to stimulate the energy transition by enabling energy storage through power-to-X approaches and contribute to a circular economy by converting waste emissions into resources (IEAGHG, 2019b, Castillo-Castillo, 2019, Zhu, 2019, CCES, 2019).	See response to 39069	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
42945	0	0	0	0	The whole chapter: more efforts should be made to be precise whether a section/ information i about energy or electricity only.	Accepted	Sigrid Kusch-Brandt	University of Padua	Germany
42947	0	0	0	0	The topic of heat as one major energy form in demand is not given enough attention, the chapter is overly focused on electricity. The topic of efficiency is also not given sufficient attention.	Taken into account. We have increased the discussion of both heat and efficiency.	Sigrid Kusch-Brandt	University of Padua	Germany
17689	0	0			This chapter provides a fantastic overview of issues in energy systems - probably the best I have ever read, except very long (I suspect, significantly over length limit). It perhaps comes over as more of a review, maybe could be focused a bit more around solutions orientation. Also see my comment on gas / LNG. It also clearly has major emphasis on technical appraisal of energy systems and technologies, more than policy or governance; it would be useful to develop the latter more in the SOD and to laiise especially with Chapte 13, along with several other chapters. I flag a few issues, notably around dynamics of change (see also my general comment about this - the pace, depth and regional scope of change seems to be accelerating and I would suggest this be indicated as a fourth theme? Also see my comment on the globalisation of gas and regionalisation of electricity (p.95) which I guess could possibly be a fifth theme, though it is certainly not presented as such in the chapter as written	Accepted: We are working hard to try to get the SOD more action-oriented. (We are almost exactly at the page limit and will not be adding more pages)	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
4443	0				Please provide a balanced presentation between technologies. Some technologies that have potential in the future are described very succintly (e.g. 6.4.2.9. ocean energy should be expanded). Solar thermal technologies are not described/discussed. Thermal storage is not mentioned. The description of waste-to-energy is very short. The descriptions of some technologies focuses mainly on electricity and could be extended to heat and fuel production.	Rejected: We have only limited space and have to put emphasis on the technologies based on the authors perceptions of their potential roles. Ocean energy and waste-to-energy are not deemed to justify the same level of space as solar, wind, hydro, nuclear, and fossil and bioenergy with CCUS. Accepted: We are including solar thermal (briefly) in 6.4; thermal storage in 6.4.	Leonardo Barreto	Austrian Energy Agency	Austria
4445	0				Please provide a balanced presentation between technologies. Some technologies that have potential in the future are described very succintly (e.g. 6.4.2.9. ocean energy should be expanded). Solar thermal technologies are not described/discussed. Thermal storage is not mentioned. The description of waste-to-energy is very short.	Same as comment 4443	Leonardo Barreto	Austrian Energy Agency	Austria
4447	0				It is important to make sure that even energy systems that rely on low-carbon energy do integrate energy efficiency as well as resource efficiency in the planning of plants and infrastructure, policy and investment decisions (e.g. the energy efficiency first principle of the EU defined by the 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, Assessing the European Union's energy efficiency policy: Will the winter package deliver on 'Efficiency First'? April 2017Energy Research & Social Science 26:72-79. Jan Rosenow, Richard Cowart, Edith Bayer, Mariangiola Fabbri). This can be achieved, for instance, by integration between energy efficiency and renewable energy policies.	Taken into account. We have increased the discussion of efficiency (see for example the expanded discussion in 6.6)	Leonardo Barreto	Austrian Energy Agency	Austria
4449	0				Suggest to consider Energy Efficiency in the executive summary as a separate point and make cross-reference/linkages to other chapters (5, demand, 9. buildings). In addition, the link between Energy Efficiency and Resource efficiency should be mentioned in the executve summary.	Rejected. Due to space constraints, we have considered energy efficiency along with all the other options for reducing energy system emissions. In addition, this chapter has a particular focus on supply side options, complementary to the many demand side chapters in this report.	Leonardo Barreto	Austrian Energy Agency	Austria
11995	0				Issues related to circular economy seems to be poorly coverd in the draft. This is an important emerging issue and it was highlighted in the scoping document under ch. 6.: "Circular economy (maximising material and resource efficiency, closing loops): insights from life cycle assessment and material flow analysis" Please consider to include this issue better . Now it is only briefly mentioned in 6.4.5	Taken into account. A broad set of feasibility issues are now considered for all the mitigation options discussed in 6.4.	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
14273	0				Comment: Often (see pages 42-44) the term CCUS is used but the U (for Utilisation) part is neglected and only the S (Storage) part is discussed. I suggest separating the term CCUS into CCU and CCS due to the specificities of each strand (technologies invlolved, infrastructure needs, economic potential, up-scaling potential, climate mitigation potential, timeline for deployment, etc.) (Bruhn et al. 2016; https://doi.org/10.1016/j.envsci.2016.03.001)	Taken into account. We cover both CCS and CCU and comment on both of their characteristics in Section 6.4. But space does not permit us to have separate sections on CCU and CCS.	Anastasios Perimenis	CO2 Value Europe (Association) - CCU Offiver	Belgium
16293	0				Consider adding a section that specifically addresses energy use by global militaries, as this sector is large and important in understanding energy transitions.	Rejected. Given limited space, the authors do not believe that this rises to the level of prominence to justify treatment relative to other issues addressed in the chapter.	Daniel Helman	College of Micronesia-FSM	Micronesia, Federated States of
16295	0				Consider adding a section to Chapter 6 describing space-based solar power and the current state of the art. The major impediment is the lack of an assigned frequency for transmission of the energy to the surface. Another issue is the possible interaction of traveling ionospheric disturbances caused by space-based solar and the potential for inducing earthquakes on the ground, as there is some evidence that these phenomena are related.	Taken into account. We have added a sentence on space-based solar.	Daniel Helman	College of Micronesia-FSM	Micronesia, Federated States of
16297	0				Consider adding a stronger treatment of the risk of nuclear arms proliferation related to deployment of nuclear power to new countries. The number of countries with nuclear power is slated to double, and the Non Proliferation Treaty was not designed with climate change in mind. See, for example, Goldemberg, J., 2009. Nuclear energy in developing countries. Daedalus, 138(4): 71-80. Notably missing from plans for adopting nuclear power in a widespread fashion to address climate change is a new international mechanism that would identify the most nuclear-arms-proliferation-resistant pathway and require that this pathway be followed. Note that Saudi Arabia is presently developing facilities for nuclear materials enrichment to fuel its planned new nuclear power program, and this may be a pretext for nuclear arms production.	Rejected. This is an important issue. But it is a very complicated issue that we do not believe we have the expertise to address in detail.	Daniel Helman	College of Micronesia-FSM	Micronesia, Federated States of

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17867	0				"It is good to see that this chapter has a section on “The Costs and Benefits of Energy System Transitions in the Context of Sustainable Development”. However, there is lack of facts in monetary values of costs and benefits of various energy system transitions. Addition of these examples would be useful for investors, businesses, households or decision makers in motivations or transitions to low carbon economy or society. This chapter can provide some examples of costs and benefits (in monetary value) of energy system decarbonisation. "	Same as comment 11519	Rawshan Ara Begum	Universiti kebangsaan Malaysia (UKM)	Malaysia
20787	0				the potential of carbon storage maybe need to discussed more fully in this chapter due to the importanc of CCS and BECCS in the net zero emissions scenarios.	Noted: The chapter has already incorporated substantial text to the treatment or CCUS	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	China
37339	0				Reference to PA "goals" is misleading. This should precisely refer always to the Paris Agreement Long-term temperature goal as spelled out in Art. 2 and related emissions mitigation pathway milestones as spelled out in Art. 4, which are to be determined on basis of best available science. Need to then refer to fact that there is only ONE temperature goal (not two!), and that IPCC SR15 has defined pathways in line with PA LTTG as low or no overshoot scenarios. Need to refer to limits to sustainable use of CDR assessed by IPCC SR15 and relevance for the milestones and benchmarks for energy transition.	Accepted: WG3 is working to create a more consistent and accurate treatment of the Paris goals across the report	Michiel Schaeffer	Climate Analytics	Netherlands
37341	0				The IPCC 1.5° special report SPM categorised pathways according to their relationship to 1.5° the global mean warming and it would be very policy relevant if this chapter also follows that categorisation to provide a reference point back to that report and how the literature has changed since 2018	Accepted	Michiel Schaeffer	Climate Analytics	Netherlands
40077	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)	Rejected: This is a topic for the policy chapter	Axel Michaelowa	University of Zurich	Switzerland
43553	0				This should include brief discussion of international cooperation via market mechanisms (CDM, JI) in the energy sector, particularly renewable energy (where the CDM in particular unleashed heavy investment and by consequence innovation and an ecosystem of practitioners .	Rejected: This is a topic for the policy chapter	Matthias Honegger	Perspectives Climate Research gGmbH	Germany
14441	1	0	175	18	Figure numbering in the text is often wrong.	Accepted	Jean-Sébastien Landry	Environment and Climate Change Canada	Canada
14461	1	0	175	18	Make sure that all abbreviations and acronyms are defined the first time they are used in the chapter.	Accepted	Jean-Sébastien Landry	Environment and Climate Change Canada	Canada
18445	1	1	1	1	There is a lot of duplications on BECCS with chapters 3 and 6, please enhance coordination among the chapters	Accepted: We hve assessd overlap with Chapter 3. At the same time, some degree of overlap across chapters is inevitable given the complexity of the systems that are being assessed in this report.	Chang Shiyan	Tsinghua University	China
28629	1	1	100	50	Thank you for the very easy to read and educational chapter.	Noted	CHRISTOPHER BATAILLE	IDDRI.ORG/SIMON FRASER UNVIERSITY	Canada
1249	1	1	126	31	The life cycle assessment tool can holistically calculate the carbon footprint of the entire cradle to grave life cycle stages of any technology following the guidelines of ISO 14040 and 14044. A similar life cycle assessment study had been conducted recently by A. Rashedi et al. on various renewable and non-renewable energy technologies and the results had been communicated in the article "Life cycle assessment of 50 MW wind firms and strategies for impact reduction (Renewable and Sustainable Energy Reviews 21 (2013) 89 - 101)". This article showed that a hydro-turbine power plant carries the lowest cradle to grave climate change / GHG emission impact to the environment within all electricity generation technologies in producing one unit of electricity. An onshore turbine plant, a nuclear, PV, natural gas, oil or coal based plant carries 2.25, 2.85, 16.11, 178.95, 261.74 and 289.30 times more climate change/GHG emission impact, respectively (see Table 2 of the article). The Chapter 6 of the IPCC report should include similar/relevant GHG comparison based studies in the text for a more robust, objective review of GHG emission of various energy technologies.	Rejected. Due to space constraints, we have not conducted a synthesis of current lifecycle GHG emissions. Rather, we have focused on articulating the broad set of feasibility factors that influence the choice of technology options, and we have focused more on the nature of future energy systems than those of today. Lifecycle emissions will be very different in fuure systems than those of today!	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
31511	1	1	126	32	Thank you for providing this comprehensive manuscript. I was positively surprised by the comprehensive introduction in the different fields and technologies. In contrast, I was somehow disappointed by the current linguistic and formatting (e.g. many additional brackets in the citations, missing dots after “et al.”, missing Figure numbers in the citations, etc.) status of the manuscript. I hope you still have the capacity to improve the whole report in terms of typos, incomplete sentences, missing as well as formally wrongly integrated references. Furthermore, in some parts the structure is improvable (e.g. the system requirements for high shares on RES, such as storage, grid extension , DR etc. can be found several times in Section 6.4).	Accepted	Patrick Jochem	German Aerospace Center (DLR)	Germany

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
44187	1	1	175	17	Unless mistaken, I found no references to blockchain, cryptocurrency, artificial intelligence or digitalisation. These are no doubt mentioned in more sector-specific chapters, but each could be a critical aspect of the energy system. There should eb some reference to them as critical drivers / uncertainties in this chapter.	Taken into Account. We explicity mention block chain in the chapter now. And while we do not explicitly use the phrase artificial intelligence, we put increasing emphasis on the management and integration aspects of future energy systems related to artificial intelligence. We do not discuss crypto currency.	Ajay Gambhir	Imperial College London	United Kingdom (of Great Britain and Northern Ireland)
13693	1	1	175	18	Substantially more attention should be paid throughout this chapter to the 'Danish model' of integrating solar thermal and inter-seasonal thermal storage into district heating systems as a game-changer for low-carbon heat - see: https://commonweal.scot/policy-library/just-warmth and references therein, plus other work by the Danish Energy Agency and Ramboll.	Taken into Account. We have put substantially more effort into our discussions of stoage tecnologies. We do not, however, specificlfically mention the "Danish Model".	Keith Baker	Built Environment Asset Management (BEAM) Centre, Glasgow Caledonian University	United Kingdom (of Great Britain and Northern Ireland)
14207	1	1	175	18	If i am not wrong, the term "energy return on energy investment" is not mentioned in this chapter. However, this is a fundamental technical performance factor to assess the viability of future societies. Renwable technologies have different EROI levels, while the consideration of more conversion chains such as synthetic fuels of hydrogene would tend to reduce the EROI of the full system. Some reporting and discussion on this should be included, especially since recent research has shown the importance of this factor with relation to the financing and the feasibility of the transition (link with Chapter 15): Carbajales-Dale, M., Barnhart, C.J., Brandt, A.R., Benson, S.M., 2014. A better currency for investing in a sustainable future. Nature Clim. Change 4, 524–527. https://doi.org/10.1038/nclimate2285 Capellán-Pérez, I., de Castro, C., Miguel González, L.J., 2019. Dynamic Energy Return on Energy Investment (EROI) and material requirements in scenarios of global transition to renewable energies. Energy Strategy Reviews 26, 100399. https://doi.org/10.1016/j.esr.2019.100399 Sers, M.R., Victor, P.A., 2018. The Energy-missions Trap. Ecological Economics 151, 10–21. https://doi.org/10.1016/j.ecolecon.2018.04.004 Hall, C.A.S., Lambert, J.G., Balogh, S.B., 2014. EROI of different fuels and the implications for society. Energy Policy 64, 141–152. https://doi.org/10.1016/j.enpol.2013.05.049 Fizaine, F., Court, V., 2016. Energy expenditure, economic growth, and the minimum EROI of society. Energy Policy 95, 172–186. https://doi.org/10.1016/j.enpol.2016.04.039 Brandt, A.R., 2017. How Does Energy Resource Depletion Affect Prosperity? Mathematics of a Minimum Energy Return on Investment (EROI). Biophys Econ Resour Qual 2, 2. https://doi.org/10.1007/s41247-017-0019-y	Taken into Account. EROI is addressed variously throughout the chapter, although there is no specific section on it. For example, the fossil section explicitly discuss EROI, and the wind section disucsses the carbon payoff time for wind turbines, which is roughly correlated with EROI. We will revisit this issues following comments on the SOD.	Iñigo Capellán-Pérez	University of Valladolid	Spain
36761	1	1	175	18	My general impression of Chapter 6. In these parts of Chapter 6 where I am an expert (PV), many sentences are so wrong, numbers so outdated, and main issues are left out, that this chapter would have no chance whatsoever to go through a reviewing process in a serious journal paper. I also have severe doubt in other, more general parts than PV of chapter 6, like 6.4, 6.6 and 6.7, but I let experts of these areas handle this. There are severe issues with Chapter 6 and I strongly recommend to get help from experts. Over periods, the present version reads like written by lay people. I mean this seriously, I am not ironic. For a report for IPCC, you have the responsibility to deliver information that is based on systematic, serious up-to-date data and clear scientific reasoning. This is by far not always the case in Chapter 6. If I had to review this for a technical journal, I would recommend rejection without revision because I would not expect that such a muddy, worldly text, where many main points are buried, has a chance to be improved sufficiently by the authors. They seem to lack the knowledge for that. For example, their described integrated assessment models seem to ignore even sector coupling, I found nothing substantial about heat pumps. No mentioning of modern standard literature such as: Sven Teske, “Achieving the Paris Climate Agreement Goals (https://www.springer.com/gp/book/9783030058425), Bogdanov (https://www.nature.com/articles/s41467-019-08855-1), Löffler, “Designing a Model for the Global Energy System-GENeSYS-MOD: An Application of the Open-Source Energy Modeling System (OSeMOSYS)” (https://www.mdpi.com/1996-1073/10/10/1468), Pursiheimo ” Inter-sectoral effects of high renewable energy share in global energy system” (https://www.sciencedirect.com/science/article/pii/S096014811831156X), and Sgouridis ” The sower’s way: quantifying the narrowing net-energy pathways to a global energy transition” (http://dx.doi.org/10.1088/1748-9326/11/9/094009), only older work from Jacobson (their newest: “Matching demand with supply at low cost in 139 countries among 20 world regions with 100% intermittent wind, water, and sunlight (WWS) for all purposes” (https://www.sciencedirect.com/science/article/pii/S0960148118301526). Also no mentioning of research overviews on 100% renewable energy systems e.g. from Hansen et al, ” Status and perspectives on 100% renewable energy systems, Energy 175 (2019) 471-480 (https://www.sciencedirect.com/science/article/pii/S0360544219304967, see also https://www.sciencedirect.com/science/article/pii/S1364032118303307).	Accepted: First-order drafts are necessarily rougher than second-order drafts. We are working to produce a stronger second-order draft and have also brought in additional expertise in key technologies, including bioenergy, and solar power.	Pietro Altermatt	R&D Center of Trinasolar	Germany

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36761	1	1	175	18	comment continued: I am regularly reviewing papers, from prestigious ones like Nature to more modest and general journals, and I must say I haven't had such a hard time reviewing as with this piece for a long time. Personally, I found it frustrating to go through page and page, and it took me a long time to get an overview and to make only the few concrete suggestions above. My problem is that most of the necessary improvements cannot be done on a sentence-for-sentence base in this Excel sheet, but relate to general quality and approach and knowledge. A possible improvement may be to review the criteria about who should be involved as authors of such a report. I can imagine that it is hard to find suitable experts who have time for writing long reports. Possibly, the work may be distributed into smaller chapters, and the manuscripts of these chapters may be sent through the existing reviewing process of journals with a sufficiently high impact factor on the related topic. In that way, existing and well-working reviewing processes could be used to guarantee the necessary quality for an IPCC report. Another suggestion for improvement: instead of mainly describing global averages and trends, I suggest to insert various boxes with a description of countries who already have a large renewable/capita share in their country or who already deploy many electric cars, or are renovating buildings to lower domestic energy use, ect. This would highlight feasible examples already in practice. I do not expect that such examples can be transferred to other countries one-by-one, but it would be better to orient ourselves on good examples than on an inert global average. The backbone of a CO2-neutral economy are the well proven mainstream technologies wind and solar, with the help from a few other technologies and system integration. With this kind of deep electrification and sector-coupling, primary energy demand would quickly saturate (for example, electric cars require about 1/5th of energy than fuel cars). Does this really stand out in this chapter 6?		Pietro Altermatt	R&D Center of Trinasolar	Germany
38035	1	1	175	18	The description of hydropower in the whole chapter of Energy systems seems not to be in line with IPCC standards. The text is many places not using objective language and not supported by evidence in the form of publications. I strongly encourage the lead author team to invite a Contributing Author with more knowledge and expertise in hydropower, includng technical, econimical, operational, hydrological, environmental and social aspects related to hydropower. This could help in making the text in line with IPCC standards	Taken into Account. We have developed a strong set of authors on hydropower, and we have improved the discussion of hydropower thorughout the chapter.	Atle Harby	SINTEF Energy Research	Norway
10149	1	1	175	40	I want to make a general comment on this chapter 6, but essentially on the whole Sixth Assessment Report, First order draft of the Working Group III. All chapters are very much biased to an electricity only system, production technologies are biased to electricity production technologies, storage technologies are biased to electricity storage and end use conversion technologies are also biased towards electricity technologies. There is no doubt that in future sustainable energy systems, most of the energy will be produced from solar and wind in the form of electricity. There is also no doubt that in end use, the share of electricity use will increase from less than 20% of final energy use today to even 50-60% in future systems. Therefore there is still a large share in other energy use, which eventually will be hydrogen or hydrogen based fuels. But the emerging awareness is that producing cheap electricity by solar and wind, especially at places with good solar irradiation or good wind speeds, means energy transport over long distances and large scale storage to bring this cheap energy at the users at the right time. And this transport is not with electricity cables and storage as electricity in batteries. For this a conversion to a molecule energy carrier (hydrogen or hydrogen based energy carriers) is necessary.which leads to less expensive energy system cost. Hydrogen is not the silver bullit or the solution for everything. However, a sustainable energy system based on a clever mix of electricity and hydrogen as energy carriers, whereby the clever mix depends on the geographic region, makes it possible to create a sustainable energy system, which is affordable and reliable. As a first attempt to design such an electricity-hydrogen system for Europe, I have written a paper ''Hydrogen, the bridge between Africa and Europe'' that have very much influenced the new EU commissioner Frans Timmermans and will be an important input for the 'Green Deal'' of the European Union. van Wijk, A., & Wouters, F. (2019, September). 'Hydrogen, the Bridge between Africa and Europe'. Retrieved from To be published in: Shaping an Inclusive Energy Transition, Springer, 2020: http://profadvanwijk.com/wp-content/uploads/2019/09/Hydrogen-the-bridge-between-Africa-and-Europe-5-9-2019.pdf	Accepted: We are working toward a more comprehensive assessment of the energy system that goes beyond electricity	Ad van Wijk	Technical University Delft	Netherlands

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
13689	1	1	175	48	Given the global overview presented in this chapter the authors may find our new edited book useful. "The Palgrave Handbook of Managing Fossil Fuels and Energy Transitions is the first volume to comprehensively analyse and problem-solve how to manage the decline of fossil fuels as the world tackles climate change and shifts towards a low-carbon energy transition. The overall findings are straight-forward and unsurprising: although fossil fuels have powered the industrialisation of many nations and improved the lives of hundreds of millions of people, another century dominated by fossil fuels would be disastrous. Fossil fuels and associated greenhouse gas emissions must be reduced to a level that avoids rising temperatures and rising risks in support of a just and sustainable energy transition. Divided into four sections and 25 contributions from global leading experts, the chapters span a wide range of energy technologies and sources including fossil fuels, carbon mitigation options, renewables, low carbon energy, energy storage, electric vehicles and energy sectors (electricity, heat and transport). They cover varied legal jurisdictions and multiple governance approaches encompassing multi- and inter-disciplinary technological, environmental, social, economic, political, legal and policy perspectives with timely case studies from Africa, Asia, Australia, Europe, North America, South America and the Pacific." See: https://www.palgrave.com/gp/book/9783030280758 The chapter on Russia is written by a particularly senior source and is so provocative that we spent a long time deliberating over whether or not to publish it.	Noted. The reference is noted	Keith Baker	Built Environment Asset Management (BEAM) Centre, Glasgow Caledonian University	United Kingdom (of Great Britain and Northern Ireland)
43687	1	1			The chapter makes many good points and rightly tracts emerging issues, such as decline in battery costs and PV. However, sector coupling is hardly considered, while being one of the main emergent dynamics, with crucial implication, especially for LCOE for coupled RE-storage systems, or coupled RE-heating/transport systems. Sector coupling would deserve a major part of the chapter. Also: it appears that there is much more recent data on PV systems, both in terms of current cost developments, but also in terms of scenarios, that could be considered. In particular, the ESM community has much to offer. While they are perhaps more on the optimistic end of RE systems, their models are calibrated well in technology specific literature.	Accepted: The PV material has been substantially improved. We have better incorporated sectoral coupling across the chapter. Integraton is a major theme in the chapter/	Felix Creutzig	MCC Berlin	Germany
9219	1		175		Energy systems will need to become “carbon-neutral” by 2050 or within several decades after 2050 to meet the Paris goals. Energy system CO2 emissions continue to increase. This is the opposite of what needs to happen to meet the Paris goals. Recent years have seen rapid improvements in several energy system mitigation options, including PV cells and batteries. Electricity generation from low-carbon sources, particularly wind and solar power, has increased substantially in recent years. While substantial, this growth is well below what would be needed to meet the Paris goals. Although there is no single “best” future carbon-neutral energy system, there are several robust characteristics that are valuable for guiding strategy. The global energy system has to be fundamentally transformed over the coming decades to meet the Paris goals. There are many technology options available today for taking the first steps to reduce energy system emissions consistent with the Paris goals. Major technological challenges will not emerge until well past 2030. Climate change may have important implications for the energy system, particularly in countries reliant on hydropower and bioenergy. The challenges of energy system transformation go well beyond technology, particularly in the near term. The viable speed and scope of energy system change will depend how well such change can support broader societal objectives and garner broader societal support. Energy system mitigation will create opportunities for some industries and associated groups while negatively impacting some industries and groups, particularly in the near-term. Every country will need to chart a course toward carbon-neutral energy systems that meets its own needs and national circumstances. If current trends continue, not only will emissions increase, but the energy system will be “locked-in” into higher emissions, making transformation even harder. Many new investments in fossil infrastructure are at risk of being “stranded” -- retired early – in order to meet the Paris goals.	Rejected: This comment is incomprehensible	Mounir Wahba Labib Risk	National Academy of Science, Egypt	Egypt

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
9219	1		175		comment continued: Figure 6.1 The energy system is the integration of the physical energy system, the institutional and operational systems, and broader natural and social systems (Clear figure & impressive and representative). Figure 6.2 Overview of the physical energy system (Source, IPCC AR5)- (needs to be revised). Figure 6.3 Change in global fossil fuels CO2 emissions over previous year (clear & impressive). Figure 6.4 Global energy-related CO2 emissions by source (clear figure & impressive).Figure 6.5 Fossil fuels CO2 emissions by sectors (clear & representative). Figure 6.6 Total Primary Energy Supply (Mtoe and %) (clear figure & impressive). Figure 6.7 Country concentration of energy supply (%) (clear & representative). Figure 6.8 Total Final Energy Consumption by Region(clear & impressive). Figure 6.9 TFC by Energy Source (IEA 2019b) (clear & representative). Figure 6.10 Global wind power cumulative installed capacity from 1 2010-2018 per region (clear & representative). Figure 6.11 Projections for future levelized costs of storage for various technologies (clear & representative). Figure 6.12 Installed renewable energy in 2018 by technology (clear & representative). Figure 6.13 Global distribution of the annual mean direct normal irradiation (DNI, kWh/m2). (clear & impressive). Figure 6.14 Total installed costs of commercial PV (up to 500kW) (needs more clarifications). Figure 6.15 Wind power density potential (clear & impressive). Figure 6.16 Global weighted average total installed costs, capacity factors and LCOE for onshore wind, 2010– 2018. Source (needs more clarifications).		Mounir Wahba Labib Risk	National Academy of Science, Egypt	Egypt
35593	1		175		The chapter is wide ranging and generally well written. The extended introductory and overall length make it more like a text book introduction to energy than the focused look at energy system change that a reader might expect. A more focused and considerably more succinct overall approach would be very useful. There is also a widespread looseness of terminology and vagueness wrt to share, percentage, fraction (of what is often omitted). The whole chapter needs a very thorough proof read.	Accepted	Robert Gross	Imperial College and UKERC	United Kingdom (of Great Britain and Northern Ireland)
35601	1		175		the word 'evolution' is used inappropriately in many places. 'Development, progress, improvement' and so on would be more accurate - for example wind, solar and storage technologies develop and improve, they do not 'evolve'. The same point can be made about the policy environment. This is important because it through direct action and agency that change is affected, not random mutation or natural selection.	Rejected. This is an interesting point and a fair one. It is possible to assign the development and change in technology and society to agency from policy makers. But it is also possible to attribute much of it to a wide range of force, only some of which will be associated with this agency. We will return to this issue again for the final draft.	Robert Gross	Imperial College and UKERC	United Kingdom (of Great Britain and Northern Ireland)
42349	1		175		Thank you for the opportunity to serve you as a reviewer. It is a great honour. I limited my review comment to chapter 6 due to time. This chapter is very comprehensive, which also tried to combine varying views of different researchers in one. Understandably, it is challenging to reconcile diverging views, specifically when a unifying framework for evaluating various research outcome is lacking. This can be clearly seen in this document. I fully agree with authors assertion that policy decision takes factors beyond the achievement of optimal system costs. I also agree with the authors decision to present all discussed transition options rather than recommending any specific path because no two countries can follow the same transition path. However, when I evaluate the document based on these criteria's I believe that this chapter's impartiality to various transition options can be questioned. At the same time, the document shows a significant mis-understanding about the physics of future energy system, particularly that depends on high variable renewable energy and storage. During my review, I focused on clarifying these fundamental issues regardless of the presence of other gaps. I fully recognize that significantly diverging results were reported by different groups, which contributed to some of the erroneous remarks/statements that I saw in this document. The diverging views are also a result of lack of unifying theoretical framework about the future energy system (not only a result of diverging cost assumptions as the document seem to emphasize), without which generating a consensus regarding related cost difference is difficult. Thus, all cost estimates should be cautiously interpreted in this document due to the presence of high techno-economic uncertainty of all kind. In my opinion, the authors have the opportunity to ignite responsible discussion between varying groups in order to motivate innovative research to close existing scientific gap and bridge the methodological difference that contributed to such varying views. At present, some dialogues for instance the case of future energy system "with nuclear" versus "without nuclear" and "100% RE" versus "no 100% RE", diminishes the big agenda of addressing climate change if it doesn't amount to, inter-alia, undermining human capability to innovate. If IPCC focuses on clarifying all the challenges of each options and points the discussion towards the more needed innovative research, I believe it can lift the agenda to a level that this subject deserve. I greatly appreciate for your attention in this regard. If you need any further information, please feel free to contact me.	Noted	Solomon Asfaw	LUT University	Finland
45427	1				Several acronyms are used with no descriptions e.g. CSP, SSUS	Accepted	Girija Parthasarathy	Thermo King	United States of America

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
45717	1				What is the purpose of the text boxes? There is little consistency about where they are placed and what they contain. e.g. state of the art? Highlights? I think these should be explained or title made more alike.	Accepted. The boxes are intended to highlight key crosscutting themes of key contemporary interest. These will continue to be improved.	anna maria sempreviva	Wind Energy Department, Technical University of Denmark, Roskilde	Denmark
46057	1				as a general comment, I was expecting more about energy saving, energy efficiency, as sources of energy and about the digital transformation that might give a contribution to energy efficiency, saving, optimization of the energy system and renewable integration.	Noted	anna maria sempreviva	Wind Energy Department, Technical University of Denmark, Roskilde	Denmark
37343	4	1	4	1	The executive summary at present trends and what is needed for renewable and low carbon energy sources the electric generation system, however the chapter covers the entire energy system and hence they need to be similar results summarised for the entire energy system. This is very policy relevant to make sure that policymakers are aware not just of the need to decarbonise the electricity system.	Accepted	Michiel Schaeffer	Climate Analytics	Netherlands
37359	4	1	4	1	ES falls behind IPCCSR15 in addressing and quantifiying milestones for the key role of phasing out fossil fuels in particular coal, then gas and oil, as well as the key role of renewable energy in particular wind and solar, as well as efficiency, with these showing strong synergy with sustainable development.	Taken into account. More information has been included in the ES, but, due to space constraints, we leave most of the details to Section 6.7.	Michiel Schaeffer	Climate Analytics	Netherlands
28093	4	1	4	2	1.The explicit organizing theme of all chapters covering mitigation should be that rapid and deep renewable electrification of everything, can quickly drive oil, gas and coal out of the economy. Because fossil fuels are responsible for 70-85% of emissions in industrialized countries this largely resolves the problem.	Taken into Account. We have substantially revised the discussion of solar power in the chapter. We have also highlighed the role of renewable energy in net-zero energy systems and the recent trends in their use. We have tried to pull out regional information where possible, but space constraints limit us from doing regional treatments. We have substantially improved the discussion of storage as well.We have substantially improved discussions of renewables integration and 100% renewables systems.	Andrew Blakers	AUSTRALIAN NATIONAL UNIVERSITY	Australia
28095	4	1	4	2	2.The text lacks cut-through. It does not state right up front that by far the most prospective way of mitigating climate change is rapid deployment of solar photovoltaics (PV) and wind. The current text buries this key trend under many words.	See response to 28093	Andrew Blakers	AUSTRALIAN NATIONAL UNIVERSITY	Australia
28097	4	1	4	2	3.Solar PV and wind are the runaway winners of the energy race. Two thirds of global net generation capaicty additions are PV & wind. The text should drive this point home in many places. PV and wind offer a straightforward and low-cost way to undercut fossil fuels. Don't waste time on all the other low-emission technologies (put them in an appendix) because they are unlikely to compete successfully with wind and solar. Please see Figure 1 from peer-reviewed paper https://ieeexplore.ieee.org/document/8836526	See response to 28093	Andrew Blakers	AUSTRALIAN NATIONAL UNIVERSITY	Australia
28099	4	1	4	2	4.The text has the wrong price for PV on p73. Since PV is the single most important tool for mitigating climate change, this is a very serious problem in the text. See PV section below for details. The current text gives the impression that rapid transition to wind and solar PV is somehow difficult, involving major upheavals. This is just not true – take a look at facts on the ground in Australia	See response to 28093	Andrew Blakers	AUSTRALIAN NATIONAL UNIVERSITY	Australia
28101	4	1	4	2	5.What is happening in Australia is globally significant. Australia is installing wind and solar 4-5 times faster per capita than the USA, EU, Japan or China. Australia will install 22 GW of wind and PV over 2018-21, which is 900 Watts per person. See https://ieeexplore.ieee.org/document/8836526 and also official Government figures at http://www.cleanenergyregulator.gov.au/csf/Pages/quarterly-carbon-market-report.html	See response to 28093	Andrew Blakers	AUSTRALIAN NATIONAL UNIVERSITY	Australia
28103	4	1	4	2	6.I make no apology for strongly focusing on Australia – this is the cutting edge of the energy transition because BOTH PV AND WIND are being rapidly deployed. The Australian experience is replicable across most of the global population at low cost. Facts on the ground in Australia belie the discouraging tenor of the current text. Australia is investing heavily in solar PV, wind, Gigawatt-scale transmission and Gigawatt-scale pumped hydro storage. Australia is the world's largest exporter of gas and coal and various highly influential interest groups are strongly opposed to renewables. Despite this, the compelling economics of wind and solar is driving a rapid transition.	See response to 28093	Andrew Blakers	AUSTRALIAN NATIONAL UNIVERSITY	Australia
28105	4	1	4	2	See Figure 5 from peer-reviewed paper https://ieeexplore.ieee.org/document/8836526 to visualise the facts on the ground in Australia. This paper has been downloaded 835 times since it was published 5 months.ago.	See response to 28093	Andrew Blakers	AUSTRALIAN NATIONAL UNIVERSITY	Australia
28107	4	1	4	2	7.By presenting averaged statistics over the globe, the text presents an amorphous and unconvincing analysis. Its MUCH better to focus on the leading countries, to show what is possible. And Australia really is the prime example, particularly since Australia (in common with most of the world) lacks the resources required for vigorous development of hydro, bio and geothermal; BUT (in common with most of the world) – has good wind and solar.	See response to 28093	Andrew Blakers	AUSTRALIAN NATIONAL UNIVERSITY	Australia

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
28109	4	1	4	2	8.Our 2017 paper showed that a 100% renewable electricity system can be constructed in Australia at low cost: see peer reviewed paper at http://www.sciencedirect.com/science/article/pii/S0360544217309568 . This paper was read by then Australian Prime Minister Malcolm Turnbull and led to developement of Snowy 2.0, a 2GW, 350 GWh pumped hydro system in Australia. It also led to a major re-think in Australia, and the realisation that 100% renewables is not very difficult. This is replicable around the world. Balancing of variable wind and solar is accomplished with stronger long-distance transmission (to smooth-out local weather) and storage (pumped hydro and batteries) and demand management. The cost of balancing a 100% renewable electricity system is about US$18/MWh [3].	See response to 28093	Andrew Blakers	AUSTRALIAN NATIONAL UNIVERSITY	Australia
28111	4	1	4	2	9.The paragraph on page 33 “First, the costs of integration are estimated to be high - up to 50% of total costs in scenarios with high penetration (Hirth et al. 2015)” is plain wrong for most of the world [http://www.sciencedirect.com/science/article/pii/S0360544217309568]. See the comment above. This sort of analysis simply does not accord with facts on the ground. Again, Australia is a globally-leading example of what is eminently possible.	See response to 28093	Andrew Blakers	AUSTRALIAN NATIONAL UNIVERSITY	Australia
28113	4	1	4	2	10.Subsequent events strongly bear out our 2017 paper. Tens of GW of new PV and wind is being deployed and GW-rated transmission and storage is under construction in a country with 25 million people. Australia is showing, in reality on the ground, that rapid transition to a variable wind/solar electricity system is possible at low cost with support from new transmission and storage (pumped hydro and batteries) and demand management. Australia has reached 25% renewable electricity (19% PV & wind, 6% hydro) and is on track for 50% in 2025. National emissions are falling as a result. Rapid increase of renewables in the Australian National Electricity Market (fraction of energy generated) as a result of 22 GW of new PV & wind being deployed over 2018-21. PV and wind constitute 99% of new generation capacity in Australia [https://opennem.org.au/energy/nem/]. The big loser from the rise of PV and wind is coal.	See response to 28093	Andrew Blakers	AUSTRALIAN NATIONAL UNIVERSITY	Australia
28115	4	1	4	2	11.Most of the global population lives in the sunbelt (lower than 35 degrees of latitude). This is where most of the increases in population, energy consumption and emissions are occurring. Sunbelt countries have very good solar resources with low seasonal variation. They lack a cold winter, have low heating loads and no need for seasonal storage. Most of them also have good wind resources within range of current High Voltage DC (HVDC) technology (3,000 km). The current text seems to come from the peculiar northern perspective of the small fraction of the global population that is living in Europe, NE Asia and north America.	See response to 28093	Andrew Blakers	AUSTRALIAN NATIONAL UNIVERSITY	Australia
28117	4	1	4	2	12.Australia is a global renewable energy pathfinder. It is a developed nation located in the sunbelt that is adopting wind and solar far more rapidly than other countries. The sunbelt countries (most of the global population) can readily bypass a fossil fuel era as their economies grow by adopting solar and wind. please review Table 1 from https://ieeexplore.ieee.org/document/8836526	See response to 28093	Andrew Blakers	AUSTRALIAN NATIONAL UNIVERSITY	Australia
28119	4	1	4	2	1.Australia is a mature market with globally-leading per capita annual deployment of PV and wind. Costs in Australia will be more reliable than almost anywhere else. The cost of PV & wind is US$30-35/MWh. The additional cost of balancing in Australia (transmission, storage and spillage) is about US$18/MWh for 100% renewables ; see http://www.sciencedirect.com/science/article/pii/S0360544217309568. Thus, the all-in cost of a 100% balanced renewable electricity system in Australia is US$50-55/MWh. This is well below the cost of any alternative new-build generation technology (including balancing costs). That is why PV and wind are 99% of new generation capacity in Australia. Its only a matter of a few years until PV & wind fall below the marginal cost of generation of coal, leading to widespread premature retirement of coal plant.	See response to 28093	Andrew Blakers	AUSTRALIAN NATIONAL UNIVERSITY	Australia
28121	4	1	4	2	2.The table on page 73 is plain wrong in respect of PV. PV costs around US$30-35/MWh in many countries (including Australia). Sure, one can find high priced PV in an immature market or somewhere cloudy or at high latitudes. But that is not where most people live. Since PV is the single most important tool for mitigating climate change, this is a very serious problem in the text. The best way to get a handle on what PV really costs is to go to look at a mature, subsidy-free, open, price-discoverable free-market in a place with good sunshine (i.e in the sunbelt). Australia really is a very good place to look. It costs US$30-35/MWh in Australia.	See response to 28093	Andrew Blakers	AUSTRALIAN NATIONAL UNIVERSITY	Australia

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
28123	4	1	4	2	3.This sentence on page 30 is wrong: “Enhancing the technical potential for PVs would require improvement in conversion efficiency of the current solar cells. The most important development in this domain is the development of perovskite cells (Petrus et al. 2017).” Perovskite has 0% of the global market. MUCH more important has been the rapid and nearly complete conversion of manufacturing from multicrystalline BSF silicon solar cells to single crystal PERC cells, with a relative efficiency increase in prospect of a quarter. This translates directly to a further reduction of $5/MWh in PV energy cost because of the leveraging of efficiency across nearly all system costs. PERC cells (of which I am co-inventor) are being deployed in greater quantity (GW) than any other generation technology (fossil, nuclear, other renewables) [5] and are already mitigating about 1% of global emissions though displacement of coal. See this peer reviewed paper, which has been downloaded more than 3000 times in less than a year. https://ieeexplore.ieee.org/document/8653319	See response to 28093	Andrew Blakers	AUSTRALIAN NATIONAL UNIVERSITY	Australia
28125	4	1	4	2	4.P32: “domestic systems are benchmarked at $ 2.7/Wdc and 12 commercial systems at $ 1.7/Wdc”. This is plain wrong. I know this for a fact since I’m buying a 6 kW Tier 1 system right now. The correct unsubsidized figure is about US$1.5/kWDC. The Australian experience is highly relevant, since Australia is far and away the largest market (per capita) for rooftop PV, with MORE THAN 10 GW installed! About 3 GW of rooftop PV is projected to be installed in 2020 [2]. The reason for this is that the cost of electricity from roof-mounted PV is ONE THIRD of the retail cost. The US experience (reported on page 32) is weird and is probably the result of artificial barriers that are easily removed.	See response to 28093	Andrew Blakers	AUSTRALIAN NATIONAL UNIVERSITY	Australia
28127	4	1	4	2	1.The storage section needs MAJOR revision Storage technology has both an energy cost and a power cost. These CANNOT be sensibly combined into a single figure. In the case of pumped hydro (which comprises 99% of global energy storage), the energy cost ($/MWh) covers the two reservoirs and the power costs ($/MW) cover the water conveyance, pump/turbine, generator and transmission. The energy and power can be independently sized. Figure 6.11 is misleading. It doesn’t state for how long the storage can operate at full power (eg 4 hours, 24 hours, 350 hours etc). Radically different storage costs result for different choices of storage time	See response to 28093	Andrew Blakers	AUSTRALIAN NATIONAL UNIVERSITY	Australia
28129	4	1	4	2	2.As a reality check, consider the Snowy 2.0 pumped hydro energy storage system (2 GW, 350 GWh) under construction in Australia (https://www.snowyhydro.com.au/our-scheme/snowy20/) to support the rapid deployment of wind and solar. The capital cost is US$3.5-4 billion. Thus, storage costs are US$10-12/kWh. Translating this into a $/MWh figure depends upon assumptions around discount rate, system lifetime, the number of cycles per year and the purpose (arbitrage, black start, seasonal storage, rotational inertia etc). It can’t be simply represented on a graph. But for the sake of the argument, cycling Snowy 2.0 once per week for 30 years means that the cost is about US$10/MWh, which is very far below the numbers presented in 6.11.	See response to 28093	Andrew Blakers	AUSTRALIAN NATIONAL UNIVERSITY	Australia
28131	4	1	4	2	3.This statement is incorrect: “The challenges are somewhat more diverse for pumped hydro storage and compressed air storage where geographic and geological challenges are also considered (p6-23)”. The author has confined their attention to river-based pumped hydro, which constitutes about 1% of the global pumped hydro storage potential.	See response to 28093	Andrew Blakers	AUSTRALIAN NATIONAL UNIVERSITY	Australia
28133	4	1	4	2	4.Section 6.4.3.1 is mostly wrong. It focuses on on-river pumped hydro, and thus ignores the 99% of potential sites that are off-river.	See response to 28093	Andrew Blakers	AUSTRALIAN NATIONAL UNIVERSITY	Australia
28135	4	1	4	2	5.Our recent study found 616,000 off-river pumped hydro energy storage sites with combined storage potential of 23 million Gigawatt-hours – this is an enormous number, about 100 times more than needed to support a 100% global renewable energy system (Figure 7). Detailed information is available about each site including latitude, longitude, head, water volume, dam volume, water conveyance, power, energy and cost-category (A-E). .Please do not make any statements about limited sites for pumped hydro storage and high environmental costs. They are simply not true: See http://re100.eng.anu.edu.au/global/index.php AND https://www.sciencedirect.com/science/article/pii/S0306261918305270 AND https://ieeexplore.ieee.org/document/8836526	See response to 28093	Andrew Blakers	AUSTRALIAN NATIONAL UNIVERSITY	Australia
28137	4	1	4	2	CV of Andrew Blakers: I am E2 Professor of Engineering at the Australian National University. My research interests are in silicon photovoltaic solar cells and renewable energy systems. I have procured $120 million in research funding for ANU. I am co-inventor of PERC silicon solar cell technology [https://ieeexplore.ieee.org/document/8653319] which currently is mitigating 1% of global greenhouse gas emissions, has 60% of the global solar market and cumulative module sales of $40 billion. I am engaged in detailed analysis of energy systems with high (50-100%) penetration by wind and photovoltaics with support from pumped hydro energy storage (for which I was co-winner of the 2018 Eureka Prize for Environmental Research).	See response to 28093	Andrew Blakers	AUSTRALIAN NATIONAL UNIVERSITY	Australia

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
28139	4	1	4	2	Most of my comments are substantive rather than line-by-line editing.The current text reads like something from 2014 rather than 2020. There has been a VAST change in the economics of PV and wind in recent years. It is a game changer. PV & wind represent the future of energy and will do nearly all the heavy lifting to solve climate change. The current text has MISSED THIS POINT. It really needs a radical overhaul, and MUCH CLOSER engagement with cutting edge recent papers and facts on the ground in places like Australia. A word document covering all of this including figures and referencesw is located at https://www.dropbox.com/s/u1ba6cd0618tz0g/IPCC%206.docx?dl=0	See response to 28093	Andrew Blakers	AUSTRALIAN NATIONAL UNIVERSITY	Australia
12017	4	1	5	47	Chapter 6 gives several findings related to advantages connected to removal of fossile fule subsidice and to use subsidice to promate low emission technologies at least in an early stage. I belive these findings also should be highlighted in the executive summary.	Rejected. Space limitations have made it difficult to get all points into the ES. We anticipate the policy chapter will address this.	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
20455	4	1	5	47	the following fundamental critique is for the entire chapter and requries reflection in several sub-sections. The present status of the chapter can induce major international and massive critique, since major state-of-the-art insights are missing, and/or are in a misleading way presented: first, there is a very poor understanding of solar PV, but it is the least cost source of electricity already today in many parts in the world and there are studies showing PV the largest source of energy (for the entire energy system) by 2050 and beyond; practically none of the leading PV experts are cited, this documents a very limited literature knowledge; a MASSIVE disclaimer has to be added that the PV cost assumptions in ALL IAMs are wrong (compare Krey et al. (https://www.sciencedirect.com/science/article/pii/S0360544218325039) and Vartiainen et al. (https://onlinelibrary.wiley.com/doi/full/10.1002/pip.3189) - more detailed comments throughout the chapter; second, the wording CCUS is not appropriate and has to be split into CCU and CCS - more detailed comments throughout the chapter; third, CCU and power-to-X is practically not existent in the entire chapter which documents again a very weak literature knowledge - more detailed comments throughout the chapter; fourth: the most important aspect of future energy systems, the strong sector coupling is practically missing in this chapter!! - this is a major failure. IAMs are very poor in that, but hundreds of other articles discuss sector coupling, which is practically ignored - how such a major failure can happen? In these 4 central aspects the entire chapter is between major revision and rejection, rather rejection. This is far below the level an AR has to be. Major parts of existing literature are obviously not known by authors and thus ignored.	Taken into Account. The chapter has been revised substantially acorss all these dimensions.	Christian Breyer	LUT University	Finland
34747	4	1	126	31	Consider inclusion of a narrative and description of the following items for a more comprehensive coverage in this Chapter: 1. Power system stability, sustainability and relaibility with a mix of generation sources 2. Load forecasting and generation expansion 3. Demand side management of customer load, micro-grids 4. Rehabilitation, re-engineering of power generation and energy assets 5. Economic operation of energy systems 6. Combined heat and power plants, generating and water de-salination plants 7. Economies of scale for generation assets 8. Stakeholder engagements	Taken into Account. We have considered the options and many are now covered in mored detail in the chapter.	Rabiz Foda	Hydro One Networks Inc.	Canada
5857	4	1			"Energy systems" have not been defined. I suspect most readers will incorrectly interpret "energy" to mean only electricity systems unless it is clearly stated that industrial and domestic / commercial heating and cooling are also included. And what about infrastructure and consumers of the energy services? Are they part of the "system"? Is transport energy demand also included in the data quoted? It is certainly not clear to me what is included and what not. The authors throughout the chapter should have clear distinctions in mind between the major sub-sections of "energy systems" when writing text. An example is page 4 line 44 where only electricity generation examples are listed under "Energy supply options". The 3rd para of the Exec summary should follow the current fourth para - both on electricity - and then the next para should contain a discussion of heat/cool - and distinguish between modern heating systems and using biomass fuelwood and dung for heating/cooking in rural areas that amounts to a considerable share of global primary energy.	Taken into Account / Rejected. We expect that most readers know that the energy system is more than electricity, so we have not added this to the ES. The chapter itself is more clear on the different parts of the energy system.	Ralph Sims	Massey University	New Zealand
20607	4	2	4	2	The argument "...by 2050 or within several decades after 2050..." makes the statement quite meaningless. What does "several" mean? Why care about "by 2050" if I can get away with "several decades" later. This becomes clearer in the following sentences, but the first sentence should have a clear and unambiguous message.	Accepted	Vassilis Daioglou	Copernicus Institute of Sustainable Development	Netherlands
31377	4	2	4	3	I wouldn't start with the option to become carbon neutral after 2050. Please delete this. Furthermore, I would change "Paris goals" to "Paris Agreement" (all over the report).	Taken into Account. We no longer mention the Paris Agreement	Patrick Jochem	German Aerospace Center (DLR)	Germany

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
37345	4	2	4	3	The Paris Agreement statements relevant for mitigation comprise Article 2 and 4 that need to be interpreted in conjunction and are thus more than just a temperature goal (see e.g. Schleussner et al. 2019, Table 1). There is only long-term temperature goal in the Paris Agreement , so there or not multiple goals as such. Article 4.1 operationalises Article 2.1, and therefore is not a goal in and of itself but driven by assessments of the best available science that show emission and energy system pathways that meet the long-term temperature goal in article 2.1.	Taken into Account. We no longer mention the Paris Agreement	Michiel Schaeffer	Climate Analytics	Netherlands
12927	4	2	4	8	This paragraph is confusing, with somewhat self-contradictory time lines!	Accepted	Prashant Goswami	Institute of Frontier Science and Application	India
23899	4	2	4	8	A comment could be included, that it is about the wordwide emissions and goals.	Accepted	Stefan Majer	German Biomass Research Centre - DBFZ	Germany
36505	4	2	4	8	Only CDR is referred as assumption for the timeline of realizing Paris goal, but emission pathway from land use change and industrial gas is also important assumption. These emissions should be added as assumption at the inside of parenthesis.	Rejected. This statement is about energy system CO2 emissions and not land use change emissions.	Takashi Hongo	Mitsui & Co. Global Strategic Studies Institute	Japan
46249	4	2	4	8	This first and very main statement does not mention the required carbon budgets and corresponding emissions decline curves needed to respect that budget, and doesn't insist enough on the urgency to start to act now. It gives the supposition of a linear decrease of 3.3 % per year needed, while the decrease in the first years should be higher according to the different scenarios of IPCC AR5 and SR15 in order to respect the budget. Such a linear decrease would not respect carbon budgets. Also it would be very useful to also give the corresponding decrease numbers for staying below 1.5 °C, which is the cherisched ultime goal of the Paris Accord. For the linear decrease scenario, without reliance on inexistant at scale DACCS technologies, the computation is as follows: According to IPCC SR15, § C.1.3 : « according to AR5 » (to be updated by AR6 WG I findings) «, gives an estimate of the remaining carbon budget of 580 GtCO 2 for a 50% probability of limiting warming to 1.5°C, and 420 GtCO 2 for a 66% probability » on 1.1.2018, with « current emissions of 42 ± 3 GtCO2 per year ». For which 100 GtCO2 should be deducted because « Potential additional carbon release from future permafrost thawing and methane release from wetlands would reduce budgets by up to 100 GtCO 2 over the course of this century and more Thereafter ». So there is a carbon-budget on 1.1.2020 of 580-100-42-42=396 for 50 % and 420-100-42-42=236 for 66 % chance to limit GW to 1.5°C (For 2.0°C it's 1500-100-42-42=1316 for 50 % and 1170-100-42-42=986 according to Table 2.2 of SR15). This leaves 236/42=5.6 years of current emissions for 66 % probability 396/42=9.4 years for (only) 50 % probability to stay below 1.5°C, and the double of years when supposing a linear decrease. Which gives a needed yearly decrease of 9 % per year for 66 % probability, and 5.3 % for a 50 % probability to stay below	Taken into Account. Please note that annual percentage increases imply a convex curve - that is faster absolute reductions in the near-term.	Beat Brunner	Lightning MultiCom SA	Switzerland
8857	4	2	4	9	The basic objective is to be Carbon neutral by 2050 to limit the température rise à 1.5°C. Stating that Energy systems must be Carbon nuetral by 2050 is not sufficient : Cement and other indutrial activities will continue to emit GHG, and AFOLU will not be GHG Neutral. It seems more adequate to set the target of Energy systems emissions to zero. This is my understanding. If I am wrong, I recommend that you explain why the target "carbon neutral" from Energy system is sufficient, with proper references. I suggest also you refer to Chapter 6,6,1 for details.	Taken into Account. We now use the phrase net-zero.	Michel SIMON	Vice Président SFENRAL	France
3167	4	2	5	47	Please indicate the Section(s) referenced for each of the paragraphs.	Accepted	Sai Ming LEE	Hong Kong Observatory	China
31265	4	2			say: … "carbon neutral" *on global average* by 2050 … i.e. add "global average".	Taken into Account. Now using the phrase, "net zero"	Urs Ruth	Robert Bosch GmbH	Germany
33231	4	2			Energy system has not to become carbon neutral formally if its emissions are compensated in other sectors notably AFOLU	Taken into Account. The text is now more specific.	Marc Darras	Association 4D	France
11993	4	3	4	4	Is it possible to quantify this and does the energy system in this context also include the transport sector? If so, please align statements here with statements in Chapter 10. If not, please explain.	Rejected. Space limitations prevent us from discussing the components of the energy system in the ES.	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
100	4	6	4	7	What is meant by "assuming no CDR outside of the energy system"? Is it supposed to be "in the absence of CDR"?	Taken into Account. The phrase has been reoved.	Govindasamy Bala	Indian Institute of Science	India
31379	4	6	126	32	I would introduce each abbreviation in each chapter when it is mentioned first and use it TROUGHOUT the chapter without introducing it again (e.g. CDR).	Accepted	Patrick Jochem	German Aerospace Center (DLR)	Germany
2101	4	6			What is CDR	Taken into Account. CDR is spelled out.	Amy Townsend-Small	University of Cincinnati	United States of America

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
5859	4	6			What is CDR? In full first time used	Taken into Account. CDR is spelled out.	Ralph Sims	Massey University	New Zealand
38803	4	6			Should CDR be spelled out as the first time an acronym is used?	Taken into Account. CDR is spelled out.	Julian Reyes	Personal Capacity	United States of America
31381	4	7	4	7	"CO2 emissions"!	Accepted	Patrick Jochem	German Aerospace Center (DLR)	Germany
16943	4	7	4	8	In Emission Gap Report 2019, "Had serious climate action begun in 2010, the cuts required per year to meet the projected emissions levels for 2°C and 1.5°C would only have been 0.7 % and 3.3 % per year on average. However, since this did not happen, the required cuts in emissions are now 2.7 % per year from 2020 for the 2°C goal and 7.6 % per year on average for the 1.5°C goal. Evidently, greater cuts will be required the longer that action is delayed." Thus the "3.3%" in line 7 shoule be double checked.	Taken into Account. We have double checked.	Qing YANG	Harvard University	China
19567	4	8	4	8	comma in red color	Accepted	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	China
34675	4	8	4	8	missing comma in the sentence: next 30 years, as compared to average growth	Accepted	Jordi Solé-Ollé	Spanish National Research Council (CSIC)	Spain
36507	4	9	4	9	"This is the opposite what…" is better to be changed to "Gap from the pathway to Paris ,,," . As a logic, "after the increase of emission, it will be reduced rapidly and catch up the way to Paris goal" is possible. As far as I know, "gap is increasing" is more common and neutral expression.	Taken into account. The sentence has been removed.	Takashi Hongo	Mitsui & Co. Global Strategic Studies Institute	Japan
37347	4	9	4	11	This sentence needs to refer to each of the main fossil fuel energy carriers and their changes since 2015, including relative contribution to the growth of CO2 emissions. This is policy relevant information that provides context to the remainder of the chapter	Taken into account. The sentence has been removed.	Michiel Schaeffer	Climate Analytics	Netherlands
38805	4	9			The phrase "this is the opposite of what needs to happen …" is unscientific language and isn't policy-neutral.	Accepted	Julian Reyes	Personal Capacity	United States of America
35701	4	10	4	10	have rose	Taken into account. The sentence has been removed.	Linda Hancock	Centre of Excellence on Electromaterials Science Deakin University	Australia
3213	4	10	4	11	but have risen by 1.1 %/year from 2015 to 2018. (Substitute "rose" by "risen")	Taken into account. The sentence has been removed.	Klaus Radunsky	retired from Umweltbundesamt	Austria
5705	4	11	4	11	risen, not rose	Taken into account. The sentence has been removed.	paul fennell	Imperial College	United Kingdom (of Great Britain and Northern Ireland)
18661	4	11	4	11	have rose by 1.1 %/year' should be 'have risen by 1.1%/year'	Taken into account. The sentence has been removed.	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
25047	4	11	4	11	Delete "Fossil fuel use rose … and 2017." as the presented numbers are not for the same period as for the emissions	Taken into account. The sentence has been removed.	Eleni Kaditi	Organization of the Petroleum Exporting Countries (OPEC)	Austria
31383	4	11	4	11	"have risen"! I would prefer to see "per year" instead of "/year"	Taken into account. The sentence has been removed.	Patrick Jochem	German Aerospace Center (DLR)	Germany
46251	4	11	4	11	Should be completed with 2019 number.	Taken into account. The sentence has been removed.	Beat Brunner	Lightning MultiCom SA	Switzerland
2103	4	11			should be "have risen"	Accepted	Amy Townsend-Small	University of Cincinnati	United States of America
38065	4	11			"have RISEN by 1.1%"	Accepted	Craig Jamieson	Straw Innovations Ltd	Philippines
24307	4	12	4	17	The competitiveness of the electric vehicles cost alone may mask the environmental impact of the replacement of all the cars. The higlight on the cost only may be misleading for people who will only read this executive summary.	Rejected. This is too much information for the ES	Alan BURLOT	Commissariat à l'énergie atomique et aux énergies alternatives	France
24309	4	12	4	17	« in many regions » is quite vague. Should we emphasize the fact that PV and batteries may be produced in caol-intensive countries ? That point may ruin all the efforts of those virtuous systems.	Rejected. This is too much information for the ES	Alan BURLOT	Commissariat à l'énergie atomique et aux énergies alternatives	France
31671	4	12	4	17	« in many regions » is quite vague. Should we emphasize the fact that PV and batteries may be produced in coal-intensive countries ? That point may ruin all the efforts of those virtuous systems.	Rejected. This is too much information for the ES	Alan BURLOT	Commissariat à l'énergie atomique et aux énergies alternatives	France
39269	4	12	4	17	I find the sentence about renewable generation cheaper than fossil might be a bit too simple. As I read it here it could be at an instant t or through a period of time. I know cost would also depend on the Energy mix but I feel a bit more precision would do better in a context where storage is not available at a large scale yet.	Rejected. This is too much information for the ES	Bruno Gavazzi	UMR7516 Institut de Physique du Globe de Strasbourg (CNRS/Université de Strasbourg	France

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
8859	4	12	4	25	To give a factual information, these two paragraph should mention that : a) the cost comparison includes a severe bias, since the PV produces kWh in a random maner, like wind turbines,, and consequently, the complete cost should include the cost of storage or the cost of alternative production mean, in order to guarantee that the expected service (kWh) wil be available when needed. If we omit this information, we are comparing costs of carrots and cabbages! b) It should be also desirable to mention that the development of installed capacity has been possible due to a strong financial support (probably several trillions of $ througout the world)	Rejected. In some instances, renewables plus storage are now the cheapest options.	Michel SIMON	Vice Président SFENRAL	France
110	4	13	4	14	Battery costs have dropped by more than half between 2015 and 2018. There are many different battery technologies. The authors should specify which battery technologies are being referred to in this content.	Rejected. This is too much information for the ES	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
112	4	15	4	15	Renewable generation is now cheaper than fossil generation….The authors should specify the type of renewable energy is cheaper than fossil fuel generation.	Rejected. This is too much information for the ES	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
6443	4	15	4	15	what has storage and PV to do with transporting (-> transmitting) electricity?	Taken into Account. The sentence has been rewritten for clarity	Paul Neetzow	Humboldt-Universität zu Berlin	Germany
27869	4	15	4	17	REPLACE/REMOVE «Renewable generation is now cheaper than fossil generation in many regions, and projections indicate that light-duty electric vehicles may be competitive with internal combustion engines in a matter of years (see Chapter 10). » REPLACE BY « Except in some favorable regions, renewable generation is not as cheap yet as fossil and fissile generation, especially when accounting for the backup systems necessary to mitigate the intermittency, the need of energy storage and the complexification of electricity grid stability; but projections indicate that light-duty electric vehicles may be competitive with combustion engines in a matter of years (see Chapter 10). »	Rejected. In some instances, renewables plus storage are now the cheapest options.	Jean-Luc SALANAVE	Ecole Centrale-Supelec, Paris, France (professor, energy systems)	France
40125	4	15	4	17	I would add thefollowing sentences: Furthermore renewable generation produces no environmental damage costs compared to fossil generation. The Federal Environment Agency in Germany recommended in 2016 a price of 180€ climate costs per ton CO2.	Rejected. This is too much information for the ES	Armin Winkler	University of Applied Sciences Upper Austria/ Global Hydro Energy GmbH	Austria
114	4	18	4	19	Electricity generation from low-carbon sources, particularly wind and solar power, has increased substantially in recent years. The authors should indicate that the rapid growth happens in developed countries. Not so much in developing countries. Many developing countries are still behind the required target.	Rejected. This is too much information for the ES	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
17691	4	18	4	20	This depends on which current trends. If the percentage growth rates (and cost reductions) in PV, wind and batteries/Evs were extrapolated for only another 10-15 years they would revolutionise the power (and transport) sectors and leave large swathes of fossil assets stranded.	Taken into Account	Michael Grubb	UCL - Institute of Sustainable Resources	United Kingdom (of Great Britain and Northern Ireland)
27871	4	18	4	20	REPLACE/REMOVE « Electricity generation from low-carbon sources, particularly wind and solar power, has increased substantially in recent years. While substantial, this growth is well below what would be needed to meet the Paris goals." REPLACE BY «Electricity generation from low-carbon sources, particularly wind and solar power, has increased substantially in recent years. While substantial, this growth is well below what would be needed to meet the Paris goals, goals which may not be met without similar growths of other low-carbon solutions such as hydropower, nuclearpower, geothermal power, heatpumps (aerothermal power) and renewable biomass. »	Rejected. This is too much information for the ES	Jean-Luc SALANAVE	Ecole Centrale-Supelec, Paris, France (professor, energy systems)	France
37349	4	18	4	20	This bullet should give some more precise information about the recent growth in renewables as well as so-called low carbon generation and how this qualitatively relates to the increase in these sources that will be needed to meet the Paris agreement long-term temperature goal	Accepted	Michiel Schaeffer	Climate Analytics	Netherlands
44757	4	18	4	25	The percentages of growth for different energy sources is a bit misleading. Although very impressive and promising growth rates for solar power and wind, they start from very low levels. I suggest that the numbers are given in absolute numbers relative to a common value (such as total energy supply) in order to make it easier for the reader to understand the context.	Taken into Account. We have included the total percentage of electricity capacity PV and wind now represent.	Daniel Westlén	Liberal party Swedish parliament	Sweden
35703	4	21	4	25	wondering why sources of statistics are not cited here is there a rule not to cite sources in the summary?	Rejected. Sources are in the chapter.	Linda Hancock	Centre of Excellence on Electromaterials Science Deakin University	Australia
13827	4	22	4	23	When mentionning the largest increase in low-carbon source, to show growth seems less relevant than absolute energy added : +217% for solar PV does not indicate if it was the largest low-carbon source added. Please report absolute growth.	Taken into Account. We have included the total percentage of electricity capacity PV and wind now represent.	Alexandre Bizeul	International Energy Agency	France
34187	4	22	4	23	figures used in these lines are not clear. Relative variations are too high. Maybe give an absolute figure ?	Taken into Account. We have included the total percentage of electricity capacity PV and wind now represent.	Antoine BONDUELLE	Climate Action Network France	France
37963	4	22	4	24	It is unclear whether the increase in electricity generation given for low-carbon electricity, solar PV, wind power, hydropower and nuclear power are really generation (TWh) or capacity (GW). Please provide data on generation	Accepted. We have clarified generation vis-à-vis capacity	Atle Harby	SINTEF Energy Research	Norway
31385	4	23	4	23	PV instead of "solar PV"	Accepted.	Patrick Jochem	German Aerospace Center (DLR)	Germany

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
27909	4	23	4	24	IPCC states, "Growth in nuclear power (6%)" Please clarify that since 2006, nuclear power production worldwide has declined, not increased. This can be seen from the data here: https://www.world-nuclear.org/information-library/current-and-future-generation/nuclear-power-in-the-world-today.aspx . Given this negative growth rate and the long time-lag between planning and operation of new nuclear (10-19 years - Section 3.3.1.1 of https://web.stanford.edu/group/efmh/jacobson/Articles/I/NuclearVsWWS.pdf as well as acobson, M.Z., Review of solutions to global warming, air pollution, and energy security, Energy & Environmental Science, 2, 148-173, doi:10.1039/b809990c, 2009) and its high cost, this begs the question as to why nuclear is even being considered in this document as an option. Given that we need 80% reduction in emissions by 2030 to avoid 1.5 C warming, not a single new nuclear plant planned today can help with that goal. The decline in nuclear is also consistent with what is stated on the bottom of Section 6, page 21. The summary should clarify what is stated in the text, which reflect the real situation.	Rejected. This is too much information for the ES	Mark Jacobson	Stanford University	United States of America
15043	4	24	4	24	first mention of CCUS, need to be explained as "carbon dioxide capture, utilization and storage"	Taken into Account. Paragraph has been revised.	Béla Munkácsy	ELTE University	Hungary
17241	4	24	4	24	What is meant by CCUS? Please explain here and not before page 71..Besides: what is the difference between CCS (carbon capture and storage) and CCUS (carbon capture utilisation and storage)?	Taken into Account. Paragraph has been revised.	Joachim Rock	Thuenen-Institute of Forest Ecosystems	Germany
34373	4	24	4	24	CCUS should be splitted into CCU and CCS: In the report, the term CCUS (Carbon Capture Utilisation and Storage) is broadly used but not clearly defined and in most cases, 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, 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 (REFERENCES:1) Cuéllar-Franca and Azapagic, 2015 (https://doi.org/10.1016/j.jcou.2014.12.001), 2) Bruhn et al.,Environmental Science & Policy 60 (2016) 38–43, 3) Arning et al., Energy Policy 125 (2019) 235–249)	Rejected. This is too much information for the ES	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
9081	4	24	4	25	Please clarify what the 80% refer to. Is it electricity generation, primary energy consumption, electricity + heat but without transport?	Taken into Account. Paragraph has been revised.	Jan Wohland	ETH Zürich	Switzerland
12019	4	24	4	25	It would be useful if the last sentence could give todays level as well ""to grow from ..% to more than 80%.."	Taken into Account. Paragraph has been revised.	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
5861	4	24			What is CCUS? Is used in same sentence as CCS later on. Cannot expect readers to understand acronyms. This paragraph is misleading without first stating the shares of the electricity mix since solar PV may have grown significantly but from a very low base. Also why have geothermal and bioenergy generation (including CHP, biogas) not been included in the text given they make a greater controbution to the mix at present than solar PV. Also why this discussion concentrates on electricity whereas heat from fossil fuels and renewable sources (solar heating, biomass, geothermal) been included	Taken into Account. The term is defined	Ralph Sims	Massey University	New Zealand
20329	4	24			CCUS' is a highly misleading wording and requires major revision. Correct is to separate 'CCU' and 'CCS'. These two aspects are COMPLETELY different, since CCU describes the reuse of CO2 (for point sources), while even CO2 direct air capture is included as DACCU. CCU of renewables sources (e.g. pulp & paper industry, or renewable energy based DAC) is part of a zero GHG emission system and also required earlier throughout the transition. CCS is used later, in particular for negative CO2 emissions. Literature for a clear separation are 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). This entire chapter requires major revision in separation of CCUS. Please also notice that many use Power-to-X (PtX) synonoumus to CCU (see also Breyer et al. for that), this should be better reflected in the entire chapter.	Rejected. Space limitiations prevent a more thorough treatment in the ES.	Christian Breyer	LUT University	Finland
6445	4	25	4	25	80% compared to what reference?	Taken into Account. Paragraph has been revised.	Paul Neetzow	Humboldt-Universität zu Berlin	Germany
37351	4	25	4	25	This sentence should give information about what is needed to meet the Paris agreement long-term temperature goal, and in that context follow the approach taken in the IPCC 1.5° special report SPM. Limiting, or holding, warming to 2°C is not consistent with the Paris agreement LTTG, and nor is it consistent with the former Cancun goal of holding warming "below 2°C". A much more precise approach to describing the results of the assessment in the context of legally binding and/or other policy goals is needed.	Taken into Account. Paragraph has been revised.	Michiel Schaeffer	Climate Analytics	Netherlands
46253	4	25	4	25	Should be completed with the required numbers for the 1.5°C golden goal of Paris Accord.	Taken into Account. Paragraph has been revised.	Beat Brunner	Lightning MultiCom SA	Switzerland

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
46255	4	25	4	25	Yearly growth number, starting in 2020 should be noted. « over the next 30 years » doesn't give any account to the corresponding carbon budget, and the need to start immediately, vs waiting to act in last years, could be misunderstood	Taken into Account. Paragraph has been revised.	Beat Brunner	Lightning MultiCom SA	Switzerland
26573	4	26	4	36	Building heating in the built environment accounts for significant energy consumption and CO2 emissions, more than for transport or electricity supply. Building heating is a low quality application by virtue of the need to maintain spaces at roughly 21 degC yet traditionally relies on using high quality energy resourcecs such as natural to satisfy demand. This is wasteful use of scarce resource considering cities produce enough waste heat that, in combination with local renewable sources (air, ground, water), could meet the entire city building heat demand, although not all feasible or viable. New strategies are required to transition bulding space heating towards a more circular approach and this would require new policies to plan for and implemennt such a change. The outcome would enable the reuse of waste heat, eliminate the use of fossil fuels and emissions of CO2 and locally harmful combusion by products (NOx and particulates). The key points are the effective use of energy resouces, i.e., using the right energy resource for an application (n contrasts with efficient use), and the use of exergy analysis to establish the most resource efficent heat supply option. Chapter 8 Urban Systems and Other Settlements eludes to these concepts in places, so this energy chapter should also highligth this emerging field of interest.	Rejected. This is too much information for the ES	Peter North	Calorem Ltd, Imperial College (part-time PhD student)	United Kingdom (of Great Britain and Northern Ireland)
26575	4	26	4	36	In the context of the above comment, add: (8) the potential for new policy approaches to transition building heating towards a more circular approach.	Rejected. This is too much information for the ES	Peter North	Calorem Ltd, Imperial College (part-time PhD student)	United Kingdom (of Great Britain and Northern Ireland)
37353	4	26	4	36	evidence is not only based on IAM and national scenarios and strategies. There is also evidence from sectoral scenarios and bottom up analysis, including an increasing body of evidence of feasibility of 100% RE, which needs to be referred to here in ES and in main chapter.	Taken into Account. Paragraph has been revised.	Michiel Schaeffer	Climate Analytics	Netherlands
31387	4	28	4	47	What about energy system models. These should be in the focus here. So please integrate "and energy system models" at the end of this line.	Taken into Account. Paragraph has been revised.	Patrick Jochem	German Aerospace Center (DLR)	Germany
37357	4	29	4	30	Use of the term "carbon-neutral", and "low carbon" needs to be carefully defined, and as well reference made to "zero" carbon systems. Carbon neutral can mean many things in the literature and it is not clear what exactly is meant in this chapter, and the same applies to "low-carbon"	Taken into Account. We are now using net-zero.	Michiel Schaeffer	Climate Analytics	Netherlands
40127	4	30	4	36	I would add the following: (8) hihger efficiencies of energy systems	Rejected. This is already in there with more efficient use of energy.	Armin Winkler	University of Applied Sciences Upper Austria/ Global Hydro Energy GmbH	Austria
11337	4	31	4	31	"CO2 from the atmosphere" should be replaced by "CO2 from the flue gas"	Rejected. We are discussing BECCS here	PINAKI SARKAR	CSIR-CENTRAL INSTITUTE OF MINING AND FUEL RESEARCH	India
37355	4	31	4	33	electrification is an important strategy also for industry, and most if not all energy related processes can be electrified directly or indirectly (through use of fuels based on renewable energy). This is missing in this statement of electrification. The summary for industry lacks the reference to need for fuels to be zero or near zero.	Rejected. This is too much information for the ES	Michiel Schaeffer	Climate Analytics	Netherlands
39323	4	32	4	33	Electrification of end use application cannot be suggested at a blanket level rather should be recommended on the basis of the breakeven emission intensity of the output specifically for transport and cooking sector in developing country with highly fossil fuel intensive grid and subjected to high T&D/AT&C losses. For example a vehicle is using CNG is shifted to electricity being supplied by a highly fossil fuel intensive grid generating power mostly in age old and in efficeint power plants, and suppled adjusting an aggregated technical loss of electric supply of more than 30-40% the resultant emission will be net postive instead of zero/negative. Take the case from India context- a CNG based 800 CC vehicle with an emission of 0.063 kg CO2/km ,proposed to be replaced with an EV with electricity consumption of around 0.1kWh/km. Therefore at a grid emission factor of 0.92kgCO2/kWh the emission intensity will be 0.092 kg CO2/km, leaving apart the interim T&D loss of 20-30%. So incase the CNG based vehicle is replaced with an EV the per km additional emission will be 0.03 kgCO2. So unless the grid intensity reaches at an emission factor of 0.6 kgCO2/kWh or below how can the shift from cng to EV is recomendable. Rather (1) fuel switch should be suggested depending upon the passanger km emission (2) EV can also be suggested in circumstances of high grid emission scenario in case the charging can be carried out /worked out through RET.	Rejected. This is too much information for the ES	Suvra Majumdar	United Nations Development Programme	India
2335	4	33	4	33	Use for CCUS full expression instead of abbreviation	Accepted	Dieter Boer	Universitat Rovira i Virgili	Spain
16945	4	33	4	33	" (3) substantially lower use of fossil fuels than today, particularly without CCUS" . This sentense should be very misleading in countries that relying heavily on coal. For example, China. If without CCUS, China can hardly achieve carbon neutral in power sector.	Taken into Account. But the fact remains that net-zero energy systems will use far less fossil fuels than today.	Qing YANG	Harvard University	China

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
46257	4	33	4	33	« (3) substantially lower use of fossil fuels than today, particularly without CCUS », doesn't stress enough the real net-zero needed imho. Proposal : « (3) no use of fossil fuels, or substantially lower use of fossil fuels than today, and in that case with CCUS »	Taken into Account. But the fact remains that net-zero energy systems will use far less fossil fuels than today.	Beat Brunner	Lightning MultiCom SA	Switzerland
27873	4	33	4	35	REPLACE/REMOVE « (4) targeted use of alternative fuels (e.g., hydrogen, bioenergy, ammonia) to substitute for fossil fuels in harder to decarbonize sectors; ». REPLACE BY « (4) targeted use of alternative fuels (e.g., biofuels, uranium, thorium, or secondary carriers such as hydrogen, ammonia) to substitute for fossil fuels in harder to decarbonize sectors; »	Rejected. This is not consistent with the meaning of the sentence.	Jean-Luc SALANAVE	Ecole Centrale-Supelec, Paris, France (professor, energy systems)	France
34377	4	33	4	35	CCUS should be replaced by CCS in point 3) and CCU should be added in point 4) as.:" targeted use of alternative fuels (e.g., hydrogen, CO2-based fuel such as synthetic methane and methanol, bioenergy, ammonia) to substitute for fossil fuels in harder to decarbonize sectors; (5) more efficient use of energy than today;	Rejected. This is too much information for the ES	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
2107	4	33			CCUS needs to be defined	Taken into Account. The term is defined	Amy Townsend-Small	University of Cincinnati	United States of America
35375	4	34	4	34	"in harder" instead of "in order"	Rejected. Don't understand the comment. The sentence makes sense.	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France
46259	4	34	4	34	This « (e.g., hydrogen, bioenergy, ammonia) » should be « (e.g., hydrogen, bioenergy from biomass residues and waste, ammonia) », as bioenergy from specifically grown plants has a net emitting carbon footprint (see e.g. DOI: 10.1111/j.1757-1707.2011.01116.x) and has significant biodiversity side-impacts (see e.g. DOI: 10.1111/gcbb.12597)	Rejected. Commercial biomass remains a meaningful option for future net-zero energy systems	Beat Brunner	Lightning MultiCom SA	Switzerland
15625	4	34	126	31	There needs to be definition and consistency of terms. E.g., "bioenergy" is used throughout and "biopowe"r is used in Executive Summary only. Definitions on these two plus other terms need to be made.	Accepted	Cheah Singfoong	Independent consultant, formerly more than 10 years with the National Renewable Energy Laboratory, USA	United States of America
10075	4	34			Harder-to-decarbonize	Accepted	Maria E. Mondejar	Technical University of Denmark	Sweden
31267	4	34			say: … alternative fuels (e.g., hydrogen, bioenergy, ammonia, *and other PtX-fuels*)… i.e. add "and other PtX-fuels" to reflect the demand for such fuels from aviation, shipping, and heavy duty/long range road transport.	Rejected. What are PIX fuels?	Urs Ruth	Robert Bosch GmbH	Germany
16947	4	36	4	36	"(7) use of some level of carbon-dioxide removal." I suggest mention BECCS and BC in this sentence, considering carbon negative emission technology is essential in the 1.5 celsius path.	Rejected. There are multiple ways to create negative emissions, and we don't want to be prescriptive here. The modeling literature is increasingly exploring multiple options for negative emissions	Qing YANG	Harvard University	China
46261	4	36	4	36	An (8) should be added, that should probably be first as (1) : « Remove or reduce energy use by sobriety. » (translated from French Sobrieté as sobriety, sometimes as « energy conservation » or « avoid use of energy ») The cheapest energy is the one you don't need by doing things differently, or not doing them at all, and this is very different from « (5) more efficient use of energy than today », which is doing the same things as today, just using less energy. Such an important point should be in the Executivy summary. Examples include : Switching public lighting off in the middle of the night, drying clothes without dryer, not heating unused rooms, etc. Litterature examples : https://doi.org/10.1016/j.healthplace.2015.05.011 , https://doi.org/10.1016/j.enconman.2019.05.070 ,	Rejected. We consider this to fall under efficiency in the context of the a short seciton like the ES.	Beat Brunner	Lightning MultiCom SA	Switzerland
23901	4	42	4	47	Technologies were introduced previously (e.g. lines 18-25); no general introduction would be needed again.	Taken into Account. Paragraph has been revised substantially	Stefan Majer	German Biomass Research Centre - DBFZ	Germany
34375	4	42	5	2	CCUS should be splitted into CCU and CCS because this statement is right for CCS, but not for CCU as large deployment of CCU technologies already exist, e.g. for the production of chemicals (REFERENCES: e.g. 1) Quadrelli et al., ChemSusChem 2011, 4, 1194 – 1215, 2) Sternberg et al., Green Chem., 2017, DOI: 10.1039/C6GC02852G., 3) Bushuyev et al., Joule 2, 825–832, May 16, 2018)	Rejected. This is too much detail for the ES.	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
12009	4	44	4	44	Consider to exchange the first mentioning of biopower with bioenergi since this sentence is about enegy and not limited to electricity.	Taken into Account. Paragraph has been revised substantially	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
15133	4	44	4	44	Highly recommend including 'hydropower' into the following line as well: 'Energy supply options include solar power, wind power, nuclear power, geothermal power, biopower, fossil or biopower with CCS'. Strange that hydropower as a renewable and as an energy source was not mentioned at all. As per IEA (December 2019), hydropower is expected to remain the world's largest source of renewable electricity generation and play a critical role in decarbonising the power system and improving system flexibility.	Taken into Account. Paragraph has been revised substantially	Aleksandr Kraevoy	UC RUSAL	Russian Federation
15181	4	44	4	44	Highly recommend including 'hydropower' into the following line as well: 'Energy supply options include solar power, wind power, nuclear power, geothermal power, biopower, fossil or biopower with CCS'. Strange that hydropower as a renewable and as an energy source was not mentioned at all. As per IEA (December 2019), hydropower is expected to remain the world's largest source of renewable electricity generation and play a critical role in decarbonising the power system and improving system flexibility	Taken into Account. Paragraph has been revised substantially	Aleksandr Kraevoy	UC RUSAL	Russian Federation
26577	4	44	4	45	add; …and energy reuse.	Taken into Account. Paragraph has been revised substantially	Peter North	Calorem Ltd, Imperial College (part-time PhD student)	United Kingdom (of Great Britain and Northern Ireland)
37965	4	44	4	45	Please include hydropower in the sentence	Taken into Account. Paragraph has been revised substantially	Atle Harby	SINTEF Energy Research	Norway
40129	4	44	4	45	"hydro power" must be added as energy supply option.	Taken into Account. Paragraph has been revised substantially	Armin Winkler	University of Applied Sciences Upper Austria/ Global Hydro Energy GmbH	Austria
40131	4	44	4	45	Nuclear power should not be a part of the energy transition, because it's a big threat for humanity in general!	Rejected. There are multiple opinions about nuclear power.	Armin Winkler	University of Applied Sciences Upper Austria/ Global Hydro Energy GmbH	Austria
40133	4	44	4	45	Biopower with CCS should only play an small role of the energy transition because of the low efficiencies.	Rejected. The paragraph is simply covering the main sources. Many studies show substantial roles for bioenergy and CCUS	Armin Winkler	University of Applied Sciences Upper Austria/ Global Hydro Energy GmbH	Austria
116	4	45	4	45	What are CCS And CCUS?	Taken into account. The term is explained.	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
12011	4	45	4	46	You may consider to add something like "and will in an early phase require complementary and targeted policy measures such as tax credits or grant funding."	Rejected. Too much information for this paragraph in the ES	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
31389	4	46	4	46	You may "(Mobile)" in front of "Energy storage" (i.e. referring to electric cars).	Taken into Account. Paragraph has been revised substantially	Patrick Jochem	German Aerospace Center (DLR)	Germany
2105	4	46			should be "technologically"	Accepted	Amy Townsend-Small	University of Cincinnati	United States of America
2109	4	46			Maybe it is better to say carbon sequestration is technically viable but has only been implemented at small scales.	Taken into Account	Amy Townsend-Small	University of Cincinnati	United States of America
5867	4		5		No mention in Exec summary of some key factors such as the carbon budget; constraints on oil/gas exploration; rate of uptake of nuclear reactors and new generation plant designs; impacts of fossil fuel subsidies; energy return on investments; full life cycle analyses. Obviously there are space constraints, but as it is written now it is fairly mundane and can be greatly improved to better impart the key messages.	Taken into Account. The ES has been revised substantially and now includes more numbers. More transition numbers could be useful in the final draft, as suggested.	Ralph Sims	Massey University	New Zealand
11105	4		5		Electrification is the key to achieve the Paris goals, and thus, promotion of electrification in energy system should be clearly written in the Executive Summary, with an exaple of targeted electrification ratio based on IPCC SR15 scenarios or IEA scenario. (see lines 17-33, page 102)	Taken into Account. This is clearly in the ES.	Midori Sasaki	industrial organization	Japan
11107	4		5		Energy is the foundation that supports all social activities including people's lives. Affordable, reliable and modern energy services is a prerequisite for the sustainable development (SDGs goal 7.1) and secure energy supply even in the extream event (war, pirates, terrorism, natural disaster, etc) is needed to protect human health and welfare.In this regard, the most important issue in energy policy in all economies is energy resilience. Descriptions on importance of enhanced energy resilience, especially in developing and vulnerable countries should be added in the Executive summary.	Rejected. Too much information for the ES	Midori Sasaki	industrial organization	Japan
11111	4		5		fossil fuel power generation cannot be a real burden for carbon neutral world (they can stop operation or install CCS if needed and CCS is an almost-ready technology) , but lock ins in the building sector(heating, hot water supply, etc) cannot abate its emission without DACCS, and may cause a big problem in a near future in achieving the Paris goal. In some areas in the US (e.g. Berkeley CA) passed a regulation to prohibit connection of gas pipes to new buildings .and thus, "need for strong policy implementation to avoid lock in in the building sector" should be mentioned in the Executive Summary (see 6.7.3.2).	Taken into Account. Buildings are mentioned for lock-in.	Midori Sasaki	industrial organization	Japan
19883	4		5		Executive summary should have clear indication about relevant sub-chapter number (6.x.y.z) so that readers could quickly go to the relevant parts.	Accepted	Takahiko Tagami	Institute of Energy Economics, Japan	Japan

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
35603	4		5		The executive summary is poorly structured and appears as a random and slightly overlapping list. I would be better to start from the problem/current performance, need in order to meet net zero, how that might be achieved (scenarios), options, issues and policy needs.	Taken into Account. We have substantially revised the ES based on discussions with the author team.	Robert Gross	Imperial College and UKERC	United Kingdom (of Great Britain and Northern Ireland)
45693	5	1	4	11	I also suggest the following reshuffling: Energy systems will need to become “carbon-neutral” by 2050 or within several decades after 2050 to meet the Paris goals. The energy system is the largest single contributor to anthropogenic emissions causing CO2 increase. As a consequence, the Paris goals cannot be met without largely eliminating energy system emissions. To reach carbon neutral Energy systems by 2050, i.e. reaching zero CO2 , would require emissions to decrease by about 3.3%/year for the next 30 years, as compared to average growth of over 2%/year from 2000 to 2018. Estimates say that: To limit temperature change to 1.5°C, Energy systems will need to become carbon-neutral around 2045-2060 To limit temperature change to 2°C, Energy systems will need to become carbon-neutral around 2060-2075. (assuming no CDR outside of the energy system). Instead, the opposite happens, the CO2 emissions induced by Energy systems continue to increase. Emissions from fossil fuel combustion and industrial processes were roughly flat in 2015, but have rose by 1.1 %/year from 2015 to 2018. Fossil fuel use rose 0.6%/yr between 2015 and 2017.	Taken into Account. The logic has been considered by the authors in revising the ES.	anna maria sempreviva	Wind Energy Department, Technical University of Denmark, Roskilde	Denmark
45691	5	1			I would write in such a way that the Bold text is the thread of the executive summary by addind conjunctions in places: e.g. "Energy systems will need to become “carbon-neutral” by 2050 or within several decades after 2050 to meet the Paris goals. Instead, CO2 emissions induced by Energy systems continue to increase, i.e. the opposite of what needs to happen to meet the Paris goals etc....	Taken into Account	anna maria sempreviva	Wind Energy Department, Technical University of Denmark, Roskilde	Denmark
45697	5	1			As the EXECUTIVE Summary is what generally is read by decision-makers, I would add a short summary also of the introduction to explain how the report has been developed and structured i.e. answering questions focusing on two aspects and through three themes.	Rejected. This is a matter of agreed up on structure.	anna maria sempreviva	Wind Energy Department, Technical University of Denmark, Roskilde	Denmark
24625	5	3	5	8	Worsening raw water specification should be added	Taken into account	Sanaz Jafarzadeh	Thermal Power Plants Holding Company	Iran
9083	5	3	5	9	Wind and solar power should be included in this paragraph as they show large growth rates and have massive potentials for further deployment. There is also a substantial body of literature that has emerged over the last years and allows to draw conclusions. Suggestion: While multiple studies have shown that capacity factors of PV and wind will only be marginally affected with large inter-model spread (Tobin 2015, Tobin 2016, Jerez 2015, Müller 2019, Reyers 2016), other metrics such as the spatio-temporal variability of wind generation will be affected by climate change with high inter-model agreement (Wohland 2017). There is potential to mitigate the effects through portfolios of different renewable generators (Jerez 2019, Peter 2019). References Tobin, I. et al. Assessing climate change impacts on European wind energy from ENSEMBLES high-resolution climate projections. Climatic Change 128, 99–112 (2015). Tobin, I. et al. Climate change impacts on the power generation potential of a European mid-century wind farms scenario. Environ. Res. Lett. 11, 034013 (2016). Jerez, S. et al. The impact of climate change on photovoltaic power generation in Europe. Nat Commun 6, 10014 (2015). Müller, J., Folini, D., Wild, M. & Pfenninger, S. CMIP-5 models project photovoltaics are a no-regrets investment in Europe irrespective of climate change. Energy 171, 135–148 (2019). Reyers, M., Moemken, J. & Pinto, J. G. Future changes of wind energy potentials over Europe in a large CMIP5 multi-model ensemble: Int. J. Climatol. 36, 783–796 (2016). Jerez, S. et al. Future changes, or lack thereof, in the temporal variability of the combined wind-plus-solar power production in Europe. Renewable Energy 139, 251–260 (2019). Peter, J. How does climate change affect electricity system planning and optimal allocation of variable renewable energy? Applied Energy 252, 113397 (2019).	This does not fit within this paragraph (section 6.5). But the suggested change is already included in other summaries.	Jan Wohland	ETH Zürich	Switzerland
16949	5	3	5	9	In this paragragh, I suggest mention the impacts on global wind energy distribution also. In a Nature Geoscience article, the authored proved with models that climate change may weaken the wind resource in the Northern Hemisphere.	Rejected. Most studies show both increases and decreses in N. Hemisphere. This fact is already included in the sentence.	Qing YANG	Harvard University	China

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
31269	5	3	5	9	climate change will also alter wind fields, therefore altering the yield of wind farms.	TBD as part of ES refinement	Urs Ruth	Robert Bosch GmbH	Germany
5863	5	3			Also solar could be affacted by increased cloud cover, and local wind regimes may change too. Ocean energy is not mentioned at all at this stage - see SRREN Chapter 7. So maybe there could be CC impacts on wave energy too. Also bioenergy covers a wide range of biomass resources, some that may be affected by CC (e.g. forests and energy crops) and others that won't (e.g. waste-to-energy, biogas from sewage and animal manures). So current statement is misleading. This whole Exec summary seems as though there is limited understanding of renewables within the author team as it seems very simplified.	Taken into acount	Ralph Sims	Massey University	New Zealand
37967	5	7	5	7	I suggest to include flood control and drought management (water management) as a factor that could increase the vulnerability of power systems: "Climate change could also increase the vulnerability of power systems through heat waves, limits on cooling water, flood control and drought management operations, seasonal disruptions in renewable power generation, and direct impacts on power system infrastructure."	Rejected. This is included in direct impacts on power infrastructure.	Atle Harby	SINTEF Energy Research	Norway
11991	5	7	5	9	Consider to include sea level rise in this list since many fossile and nuclear power plants are located at the coast.	Rejected. This is included in direct impacts on power infrastructure.	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
12013	5	10	5	15	You may consider to include text about advatages related to a "just transition" in this para. Ref page 17	Taken into Account. We have noted just transition in the paragraph on fossil phaseout.	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
24311	5	10	5	15	The executive summary does not emphasize enough the fact that dramatic breakthrough in technology are needed for some energy system development (smart grids for instance). This paragraph may be the good place to remind the reader that we must act now and not to wait for possible technics to be descovered.	Taken into account. The ES has been substantially revised. The degree of urgency should be clearer now.	Alan BURLOT	Commissariat à l'énergie atomique et aux énergies alternatives	France
31271	5	10	5	15	Be more explicit as to what societal and individual changes you are refering to; give examples.	Taken into Account	Urs Ruth	Robert Bosch GmbH	Germany
45695	5	12	4	17	Indication of the price of the renewables	Taken into Account. The paragraph includes the cost reductions in renewables.	anna maria sempreviva	Wind Energy Department, Technical University of Denmark, Roskilde	Denmark
118	5	16	5	16	The viable speed and scope of energy system change will depend 'ON' how well such change can support….	Accepted	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
33229	5	16	5	18	"The energy system is fundamental…" If we refer to energy system as the organisation of energy collection and distribution, here it should be written that "Energy is fundamental to many of the most…" independently of the way it is managed. Such a difference is important in order to replace energy efficiency and the reduction of energy demand in a development pathway aiming at GHG neutrality. No many realises the power and energy provided by fossil fuels..., compare to human power, therefore compare to mainly pre-industrial civilisation. Furthermore, such an approach allow to distinguish energy from other intermediary goods, beacuse it represents the power of transformation and of implementing order in an entropic approach.	Taken into Account. Sentence has been removed.	Marc Darras	Association 4D	France
2111	5	16	5	22	Is it redundant to say that the energy system is linked to "energy security"? Also, what about transportation/mobility as one of the basic services? Otherwise I like the statement that "transformation will not occur if it is in conflict with these goals", but I might use the term "transformation will not occur if it limits access to any of these goals" - and somehow get air and water pollution out of that list, it would be a positive benefit if these were reduced!	Taken into Account. Air pollution is listed. It doesn't seem to that energy security and the energy system are redundant. The last sentence makes more sense in its current form.	Amy Townsend-Small	University of Cincinnati	United States of America
6447	5	22	5	23	*emission* mitigation	Taken into Account	Paul Neetzow	Humboldt-Universität zu Berlin	Germany
120	5	23	5	23	Energy system mitigation will creat opportunities OR CO2 mitigation will create opportunities…	Taken into Account	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
122	5	23	5	23	Energy system mitigation will create opportunities….This is too absolute. The authors should make this as a possible pathway in the future.	Rejected. The previous paragraph is focused explicitly on the negative effects of stranded assets.	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
3215	5	23	5	24	The following wording is suggested: Energy system mitigation will create opportunities for some industries and associated groups while negatively impacting other industries and groups, particularly in the near-term. (Substitute "some" by "other").	Rejected. The previous paragraph is focused explicitly on the negative effects of stranded assets.	Klaus Radunsky	retired from Umweltbundesamt	Austria
34139	5	23	5	24	Repetition :Energy systems mitigation …. while negatively impacting others.[suggestion ENSEEIHT INP]	Rejected. The previous paragraph is focused explicitly on the negative effects of stranded assets.	Antoine BONDUELLE	Climate Action Network France	France
11339	5	23	5	25	"and value of fossil fuel" should be omitted	Taken into Account. Paragraph has been revised.	PINAKI SARKAR	CSIR-CENTRAL INSTITUTE OF MINING AND FUEL RESEARCH	India
2113	5	23	5	30	And of course fossil fuel industries are a major political force globally. Worth adding?	Rejected. It is an excellent point, but it is being treated a bit more implicitly here. It may be that some of the social science chapters take this on more explicitly.	Amy Townsend-Small	University of Cincinnati	United States of America
23903	5	23	5	30	Solutions will be made also considering how the challanges can be faced (page 5, lines 10-15),	Noted	Stefan Majer	German Biomass Research Centre - DBFZ	Germany

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
35705	5	25	5	25	'societies that dependent' – ed. That are dependent	Accepted	Linda Hancock	Centre of Excellence on Electromaterials Science Deakin University	Australia
46263	5	26	5	27	The need of social accompaigning measures for workers from fossil fuels industry (reconversion, clean jobs, etc) should be explicitely mentioned here. Not only commercial and financial interests, but also human interests. Examples include support of fossil fuel workers for keeping a job and lifelyhood income in Canada.	Taken into Account	Beat Brunner	Lightning MultiCom SA	Switzerland
5865	5	26			"dependent" to depend	Accepted	Ralph Sims	Massey University	New Zealand
8861	5	27	5	28	I recommend to add in this sentence that Hydro and nuclear power -as carbon free electricity production tools- are expected to develop in several countries. The above paragraph are celebrating wind and PV Power, and the reader must know that the total need of electricity wil require the development of ALL carbon free production tools. So far, there in no consensus on the feasibility of 100% renewable energy, all the reports supporting this idea being challenged on scientific or social basis.	Rejected due to space limitations.	Michel SIMON	Vice Président SFENRAL	France
43721	5	27	5	30	Useful to say if the $700bn per year in 'low carbon electricity generation' relates to a specific scenario, assessment or otherwise whose estimate.	Taken into Account. Sentence has been removed from the paragraph in the current version.	Kirsty Hamilton	Chatham House (Associate Fellow, unpaid)	United Kingdom (of Great Britain and Northern Ireland)
6331	5	28	5	28	Page 5 28 - energy systems mitigation - what about investment in low-carbon heating/cooling? If estimation are available it would be worthy to add them	Rejected. Too much detail for the ES.	Sciacovelli Adriano	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
124	5	31	5	31	The authors should not use the verb "will" to make it so certain.	Taken into Account. Sentence has been removed from the paragraph in the current version.	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
9085	5	31	5	35	Given that international collaboration can play a massive role in rapid energy transformations (e.g., via transmission infrastructure or alternative fuels) I would suggest to also mention this here. Thinking within country boarders does not necessarily help and some of the policies are even developed at a multi-national level.	Rejected. This is probably for the policy chapters.	Jan Wohland	ETH Zürich	Switzerland
37361	5	32	5	32	the IAM literature uses the term 'cost-effective' rather than 'economically optimal' as not all models solve for optimality, but rather a low-cost feasible solution (not guaranteed to be optimal)	Accepted	Michiel Schaeffer	Climate Analytics	Netherlands
24667	5	36	5	36	it should be added that the current trend does not anticipate the need to reduce emissions.	Rejected. This is already clear.	Florent LE STRAT	ELECTRICTE DE FRANCE	France
17693	5	36	5	38	As above (p.4 line 18 comment) - it depends on which current trends. If we are in a dynamic S-surve substitution process with percentage growth rates only declining slowly, this would revolutionise the power and transport sectors in 10-15 years. Perhaps note briefly the continued underestimates - We seem to lack the theories, models and metrics to evaluate ... ?	Taken into Accont. The phrasing has been changed to "current investment trends".	Michael Grubb	UCL - Institute of Sustainable Resources	United Kingdom (of Great Britain and Northern Ireland)
2115	5	38			I would add pipelines here along with power plants and buildings	Taken into account. Power system infrastructure includes pipelines.	Amy Townsend-Small	University of Cincinnati	United States of America
9087	5	41	5	42	Suggest to add reference to this study which explicitly looks at sea-level rise and electricity infrastructure. Bierkandt, R., Auffhammer, M. & Levermann, A. US power plant sites at risk of future sea-level rise. Environ. Res. Lett. 10, 124022 (2015).	Rejected. No references in the ES.	Jan Wohland	ETH Zürich	Switzerland
2117	5	43	5	47	Natural gas only provides reductions in CO2 emissions. I would add "it too creates CO2 emissions and also adds to the atmospheric CH4 burden"	Rejected. While thi is true, it's probably too much detail for the ES.	Amy Townsend-Small	University of Cincinnati	United States of America
19885	5	43	5	47	The tone is too assertive and should be more nuanced in such way as "Some new investments in fossil infrastucture could be at risk of being "stranded" --retired early -- should governments siginificantly strengthen policies to meet the Paris goals", The argument of "stranded assets" risk presented is based on the assumption that the governments will take whatever drastic actions to achieve the Paris target while the current situation is not like that. If governments take policies obliging still usable assets to retire, they will be subject to litigation risks and be required to pay compensation. Such probability could be particularly low in developing countries.	Taken into Account. We have revised the paragraph substantially.	Takahiko Tagami	Institute of Energy Economics, Japan	Japan

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
39325	5	43	5	47	The suggestion towards retirement of existing fossil fuel power plant is agreeable because most of the conventional power plants are old and operate at comparatively low efficiency. However the suggestion on complete transition from fossil fuel including transition from low emission intensive fossil fuel like natural gas based power generation to zero emission based power generation like solar PV, triggers some pertinent question (a) is technology like solar PV or wind along with battery/storage system considering its life cycle emission can really be considered as zero emission source - document suggest solar system having emission of 40 gm CO2/kWh (NREL) and 56 to 494 kilograms of carbon dioxide per kilowatt-hour of battery capacity (kgCO2/kWh) (b) In developing country like India having high population density and existing lands being predominantly converted/used for agricultural/livelihood activities including conversion of forest land, what should be the judicious share of solar based capacity addition so that the food security is not impacted and at the same time does not impact the adaptive capacity of the pro poor population. The idea is not against promotion of solar or wind based RET rather considering a judicious mix resulting in lowering of grid emission intensity, with major focus on lowering of energy demand without impacting the human development through adoption technology innovation and efficient practices. Suppose we compare the life cycle emission considering all the aspects from two type of power generation units 1st a 6*660 MW ~3960 MW newly constructed ultra mega super critical coal based thermal power plant with CCUS and using low ash coal and operating at an average PLF of 80% and second the solar PV. The solar PV system for generating equivalent amount of power after considering as high as 20% PLF should be designed around for an capacity of 15000 MW. For solar the life cycle emission should consider into account the life cycle emission of battery including its replacements.	Rejected. Current lifecycle emissions are not relevant. What is relevant is lifecycle emissions in the future when emissions are much lower.	Suvra Majumdar	United Nations Development Programme	India
39325	5	43	5	47	Comment continued: Now if we consider the land requirement for the thermal power plant, the same will be in tune of 44 hectare as against the land requirement of over 24000h for solar PV unit of 15 GW which is 500 times more land parcel requirement. So if the additional land area required for solar in compared to the thermal power plant is converted to forestry activity and considering the associated sequestration potential (emission from power plant - sequestration from forest) the life cycle net emission for both the power generating option be compared the situation might be completely different. Moreover the enhanced resilience due to increased forest if considered will further toughen the decision making process. However considering the challange of energy security it is pertinant to promote renewable, so inspite of the blanket suggestion of transition to renewable a breakeven path should also be proposed.		Suvra Majumdar	United Nations Development Programme	India
11117	5	44	5	44	all the fossil fuel related investments (mining, transfer, usage) without CCUS are inconsistemt with the Paris goal. Delete "particularly coal generation" and revise the text to read "New investments in fossil fuels without CCUS are inconsistent with the Paris goals."	Reject. Investments in coal generation are particularly problematic.	Midori Sasaki	industrial organization	Japan
34379	5	44	5	44	CCUS should be replaced by CCS.	Reject. We are using CCUS for simplicity in the ES.	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
27911	5	44	5	45	IPCC states, "New investments in fossil generation, particularly coal generation, without CCUS are inconsistent with the Paris goals." This statement should be clarified to state that investments in fossil fuels with OR without CCUS are inconsistent with the Paris goals. As clearly shown with data and accounting for all relevant emissions, not just stack emissions, CCUS hardly reduces CO2e wihile increasing air pollution and mining. 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. CCUS is alsways an opportunity cost relative to investing the same money in clean, renewable electricity to replace fossil electricity, as shown in the paper. See also Sekera, J., and A. Lichtenberger, The carbon capture conundrum: Public need versus private gain, A public policy perspective on carbon dioxide capture, 2020, https://drive.google.com/file/d/1K-BIULOUtfSs5LVCS9ONaDzq7jeFmO-b/view.	Rejected. The statement is making clear that coal with CCUS is particularly problematic.	Mark Jacobson	Stanford University	United States of America
12015	5	44	5	47	Consider the balance here. For fossil fuel it only focus on new investmenst while for natural gas the formulation seem to be stronger "must be retired", but issues related to early retiredment may be even more relevant to other fossil fuels?	Rejected. The sentence before focuses on all fossl investments. The balance should be fine.	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
46265	5	45	5	46	“While natural gas generation provides near-term reductions relative to coal-fired generation” is true only at the electricity-generator. When including methane emissions during exploration, extraction, transport and use, it is much less interesting: e.g. https://link.springer.com/article/10.1007%2Fs10584-011-0061-5 , https://www.pnas.org/content/109/17/6435 , https://onlinelibrary.wiley.com/doi/full/10.1002/ese3.112 , hence the expression “natural gas is NOT a bridge-fuel”.	Taken into Account. We believe the statements are consistent with this notion.	Beat Brunner	Lightning MultiCom SA	Switzerland
37363	5	46	5	46	The term 'retired' here is ambiguous. All plants are retired at the end of their lifetimes. It should be clarified that plants in this situation would need to be retired 'before the end of their economic lifetime' or 'become a stranded assest'.	Taken into Account. Statement has been clarified.	Michiel Schaeffer	Climate Analytics	Netherlands
35707	5	47	5	47	summary should probably discuss some of the national and international policy levers eg finance that could accelerate zero emission energy.	Rejected. We are leaving that to the finance and policy chapters.	Linda Hancock	Centre of Excellence on Electromaterials Science Deakin University	Australia
37969	5	47	5	47	I think the word "oil" or "petroleum" or similar is missing in the sentence betwee "refining" and "may"	Accepted	Atle Harby	SINTEF Energy Research	Norway
17359	6	1	6	8	According to discussions held during COP25 and lack of international consensus in IPCC special report on the impacts of global warming of 1.5 °C above pre-industrial levels, the mentioned texts should appear to be reviewed.	Rejected. It is not clear what this comment means	Zeyaeyan Sadegh	Islamic Republic of Iran Meteorological Organization (IRIMO)	Iran
19869	6	1	126	31	In whole chapter there are various editorial errors such as, in some cases: (i) Figures/Tables and are not referred in text. (ii) Sources are not in Reference list i.e., page 52 line 30, (Mahmood ARSHAD et al, 2019). (iii) Abbreviations (including energy units) have been used without explanation.	Accepted	Ghulam Rasul Athar	Pakistan Atomic Energy Commission	Pakistan
45699	6	1			The Introduction, explaining the structure of the report might be confusing at first reading. The development of the Chapter in answering questions focusing on aspects and touching three themes is a bit challenging for an immediate understanding from a high-level busy stakeholder. Here, I would have a figure explaining the concept. I would point out from the beginning that each section is devoted to answering questions focusing on two aspects and three themes	Accepted. We have removed the three themes for space.	anna maria sempreviva	Wind Energy Department, Technical University of Denmark, Roskilde	Denmark
126	6	2	6	2	The energy system is the main contributor to climate changeS.	Accepted. The sentence has been improved.	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
1123	6	2			Provide reference for the statement "The energy system is the main contributor to climate change". One basic tenet of scientific writing is correct citation of previous works which strengthens the credibility of the underlying study.	Accepted. We simply referred to Chapter 2.	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
2119	6	2			I suggest replacing main with largest	Accepted	Amy Townsend-Small	University of Cincinnati	United States of America
31273	6	2			y axis should be zoomed-in to better show the range for low costs. California and Arizona should have much lower LCOEs than e.g. Germany. UAE has seen PPA with less than 2 ct/kWh, and Arizona should be less than 4 ct/kWh for sure. I am confused to see much higher values in your diagram.	Rejected. I think this applied to a different section.	Urs Ruth	Robert Bosch GmbH	Germany
128	6	3	6	3	This and the other chapters……"What is 'this'?	Noted - No Longer Relevant. This passage has been removed to save space.	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
130	6	4	6	4	energy sector mitigation or CO2 mitigation or climate change mitigation? Also Each chapter explores….which chapter?	Noted - No Longer Relevant. This passage has been removed to save space.	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
132	6	7	6	7	Within the broader context of this overall assessment,….This chapter is dealing with the assessment of what? I thought that this chapter presents the options and challenges of energy sectors. It is not an assessment at all.	Noted - No Longer Relevant. This passage has been removed to save space.	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
45701	6	7	6	14	The difference between these two aspects is not clear from the wording. The sentence "While specific end use mitigation options are discussed in other chapters, this chapter discusses the integration of end use mitigation into an overall energy system perspective" should perhaps go at the beginning.	Accepted. We've clarified	anna maria sempreviva	Wind Energy Department, Technical University of Denmark, Roskilde	Denmark
34141	6	7	6	16	Structure of the paragraph makes it hard to see the two points made. Line break ?[suggestion ENSEEIHT INP]	Accepted. We've clarified	Antoine BONDUELLE	Climate Action Network France	France
134	6	8	6	8	end uses or end users?	Accpted. Now both	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
26579	6	8	6	9	add; …and energy quality	Rejected. Not the point	Peter North	Calorem Ltd, Imperial College (part-time PhD student)	United Kingdom (of Great Britain and Northern Ireland)
136	6	9	6	9	Transportation should be replaced by transmission of energy.	Accepted. It's not both.	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
6333	6	9	6	9	make sure that 'transportation' is defined clearly and used consistently in the chapter. the first thing that pops up in mind is the transportation section, however the term here seems referring to transportation of energy	Accepted	Sciacovelli Adriano	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
138	6	11	6	11	mitigation opportunities and challenges of what?	Rejected. This needs no clarification	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
140	6	11	6	48	I think that the team should rewrite the introduction because it is poorly done at present. There are so many unclear statements in the introduction.	Accepted. The iintroduction is now substantially shorter so space can be used later in the chapter.	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
29983	6	15	6	16	Consider including Chapter 12 in this list, as the Food Systems section in that chapter also includes reference to mitigation of energy use	Accepted	Brett Cohen	The Green House consultants	South Africa
23905	6	18	6	18	Instead of "what is an energy system", "what are the elements of an energy system"	Accepted - Note that the meaning has been adjusted slightly.	Stefan Majer	German Biomass Research Centre - DBFZ	Germany
14375	6	21	6	24	Should nuclear power be discussed in its own section? Same could be said for large scale hydro. Both are long established sources of low-low carbon energy. They are significant sections later in the chapter.	Noted. These are discussed in their own subsections.	Michael Bradshaw	University of Warwick	United Kingdom (of Great Britain and Northern Ireland)
14377	6	22	6	36	CCUS is not an energy source, it enables other technologies to be low(er) carbon. Should there be a separate more substantive section on CCUS—link across to assumptions about availability in pathways modelling?	Noted. CCUS isdiscussed in their own subsections.	Michael Bradshaw	University of Warwick	United Kingdom (of Great Britain and Northern Ireland)
5869	6	23	6	27	Crops grown for biomass (not "bioenergy crops") can be used for bioenergy - but also for bio-materials, bio-chemicals, bio-plastics, green hydrogen and indeed anything that petroleum can produce. Also solar heat not mentioned. Also pipelines not mentioned as a means of transporting energy carriers.	Rejected. This seems to be referring to another section. This paragraph is not mentioning specific technologies.	Ralph Sims	Massey University	New Zealand
14379	6	24			In this section need to consider the limits to state support in systems that value and protect market competition—this is a source of friction in the EU, for example.	Rejected. This section is an introduction to the chapter.	Michael Bradshaw	University of Warwick	United Kingdom (of Great Britain and Northern Ireland)
1623	6	28	6	29	Should this be disadvantaged by climate change?	Noted - No Longer Relevant. This passage has been removed to save space.	Jenkins Rhosanna	University of East Anglia	United Kingdom (of Great Britain and Northern Ireland)
44597	6	30	6	34	"climate-neutral" energy systems popping up three times already here. I guess you mean "carbon neutral", and the difference should be more clearly clarified later (6.6), when you explain both concepts	Accepted. A common definition is being developed across WG3	Oliver Geden	German Institute for International and Security Affairs	Germany
37365	6	30	6	35	The use of the term 'climate neutral' here is highly ambiguous and in fact not in line with the definition provided later in the chapter on page 6-82 lines 3-8. There, it states that 'Carbon neutral energy systems ... produyce no carbon on net', while here the statement is 'climate-neutral energy systems ... emit no CO2 or actually sequester CO2'. By the reports own defition, the term in this paragraph should be 'carbon neutral', and all references of 'climate neutral' here should be removed.	Accepted. A common definition is being developed across WG3	Michiel Schaeffer	Climate Analytics	Netherlands
26581	6	31			add: - those that reuse energy.	Rejected. Not on topic	Peter North	Calorem Ltd, Imperial College (part-time PhD student)	United Kingdom (of Great Britain and Northern Ireland)
14381	6	32			Is there a problem of overlap and repetition with some of the material in chapter 2?	Noted. There is always overlap across chapters. There is no way out of that.	Michael Bradshaw	University of Warwick	United Kingdom (of Great Britain and Northern Ireland)
6335	6	33	6	33	clarify what way-point precisely means	Noted - No Longer Relevant. This passage has been removed to save space.	Sciacovelli Adriano	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
1125	6	35			Write briefly what does it mean by 2 and 1.5 degree celcius	Rejected. This does not need to be defined in each chapter.	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
17361	6	37	6	41	According to discussions held during COP25 and lack of international consensus in IPCC special report on the impacts of global warming of 1.5 °C above pre-industrial levels, the mentioned texts should appear to be reviewed.	Rejected. The comment is not clear	Zeyaeyan Sadegh	Islamic Republic of Iran Meteorological Organization (IRIMO)	Iran
11341	6	39	6	45	I do fully agree to the statement of low confidence on the feasibility of the pathways for limiting the temperature change to a particular level. Economic viability of new energy systems with or without CCUS is very difficult to establish.	Noted	PINAKI SARKAR	CSIR-CENTRAL INSTITUTE OF MINING AND FUEL RESEARCH	India
11343	6	39	7	21	It is very important portion and may be considered to be highlighted under a separate sub-heading, “Theme of the Assessment”	Rejected. This is too short of section for subsection headings. In addition, the secton has been substantially reduced in length to save space.	PINAKI SARKAR	CSIR-CENTRAL INSTITUTE OF MINING AND FUEL RESEARCH	India

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
17695	6		6		At least for mainstream energy industry readers, aside from the vacillations of the oil markets, the really big transfomation has been in gas - and particularly, most dramatically, in the collapse of Asian LNG prices from almost 12 to around $4/MMBTU. This must fundamentally challenge the economics of current coal construction. I'm not an LNG expert but there seems to be a sizeable surplus, and the Oxford INstitute (OIES) projects that low LNG prices could persist for at least a decade. If decisions are economically rational and somewhat risk-averse this surely would be expected to drastically reduce coal build and stranded asset risk of coal, but raises the parallel question of gas. Shell have suggested LNG capacity could double. If so, the options for decarbonising gas/LNG during the 2030s take centre stage. I think this coudl be flagged in the introduction and would justify significantly expanding the later discussion on 'decarbonising gas'	Rejected. This is not topic for the introduction, which is only focused on introducing the topics of the chapter and not its conclusions. But it may be something that needs to come out more in Section 6.3.	Michael Grubb	UCL - Institute of Sustainable Resources	United Kingdom (of Great Britain and Northern Ireland)
5871	6		10		Much of these sections 6.1 and 6.2 can be cut. Concentrate on what is new since AR5. Is meant to be an assessment of the literature, yet not a single reference is quoted in sections 6.1 and 6.2. Reads like Energy 101!	Accepted. We have substantially cut 6.1 and 6.2	Ralph Sims	Massey University	New Zealand
18835	6		115		In parallel to energy system models, a growing body of research uses geospatial data for electrification planning (Bertheau, Cader, & Blechinger, 2016; Mentis et al., 2015; Ohiare, 2015; World Bank, 2016a).	Noted	Michael Ugom	University of Nigeria, Nsukka	Nigeria
33233	7	1	7	7	This is an essential pargraph to evaluate scenarios. However, as I mentionned earlier, the use of Sustainable development goals or Agenda 2030 is improper here as it is a set of urgent measures to implement before 2030 to be on a sustainable pathway. It will ne closed in 2030 and do not cover all issues of sustainable development. Therefore, one should use sustainable development as in the second sentence.	Noted - No Longer Relevant. This passage has been removed to save space.	Marc Darras	Association 4D	France
33235	7	1	7	7	In order to avoid a misunderstanding between "sustainable development" and "sustainable development goals" of Agenda 2030, and to benefit of the success in terms of communication of the coloured square of the presentation of the SDG's, I suggets that you introduce a box at the very beginning, in chapt. 1, to clarify this point, and that you referonly to the squares a elements of SD, and that you do not strictly obey the implementation of Agenda 2030. I further draw your attention to SDG 17, which collect transverse means for SD, and the corresponding targets for 2030: as such it is not an element of SD but a mean to achieve it.	Noted - No Longer Relevant. This passage has been removed to save space.	Marc Darras	Association 4D	France
16953	7	4	7	7	In the introduction section 6.1, I suggest to provide some statements of the environmental and ecological impacts from renewable energy system, when talking about the linkage to sustainable development.	Noted - No Longer Relevant. This passage has been removed to save space.	Qing YANG	Harvard University	China
33237	7	10			"perspective on nuclear power" the societal preference is not only on nuclear, but on large hydro, (and even small for water sharing), unconventional oil and gas, wind energy... I suggest to simply mention"energy technology".	Accepted. Offending phrase has been removed.	Marc Darras	Association 4D	France
33239	7	11			under economic development you should mention the question of repartitionof revenue and capital.	Rejected. We are shortening the entire paragraph and removing examples.	Marc Darras	Association 4D	France
33241	7	12			under political factors (not only economy) you should rather phrase it" balance of power between group of interest and political governance" which includes all groups of interest being social, ethnics, and economic	Accepted	Marc Darras	Association 4D	France
43723	7	19	7	20	I want to comment positively on the reference to 'provide guidance that might be valuable for national decision-making'. This is an important point for other chapters.	Noted - No Longer Relevant. This passage has been removed to save space.	Kirsty Hamilton	Chatham House (Associate Fellow, unpaid)	United Kingdom (of Great Britain and Northern Ireland)
38807	7	21			The word “influence” seems to connote policy prescription. An alternative formulation could be “identify how particular national characteristics might be policy-relevant for mitigation options and pathways”.	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Julian Reyes	Personal Capacity	United States of America
44599	7	22	10	26	This really is an excellent framework for this chapter - but although 6.2 is conceptual, it probably needs some support by existing literature, doesn't it?	Noted. It is our perspective that this does not need a citation, as this is the synthetic perspective of the authors	Oliver Geden	German Institute for International and Security Affairs	Germany
6113	7	23	7	25	Energy system extending well beyond this physical (energy) system to include the broad set of societal and institutional systems in which energy technologies are embedded rather becomes an ENERGY SECTOR.	Noted	Joseph Essandoh-Yeddu	Energy Commission	Ghana
15567	7	23	7	25	" Energy system extending well beyond this physical (energy) system to include the broad set of societal and institutional systems in which energy technologies are embedded rather becomes an ENERGY SECTOR. " Energy System by the industry standard is limited to only the physical system value chain or life cycle analysis; from generation to consumption or use.	Noted	Joseph Essandoh-Yeddu	Energy Commission	Ghana

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
142	7	23	7	28	How does the energy system include societal and insttitutional systems? How can this broader view be essential for energy system mitigation?	Rejected. This will be addressed throughout the chapter and the report, which is why there are sections and chapters on a wide variety of socetal issues.	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
10131	7	23	9	3	Chapter 6.2 Elements of Energy Systems, the physical energy system as depicted in Figure 6.2 has some fundamental omissions and mistakes. The most important are. 1. Only electricity/battery storage is represented, but large scale seasonal storage of gas and heat is not represented. To give as example the large scale seasonal gas storage in Europe, resulting from the higher gas demand in winter time than in summer time for heating. Gas is produced the whole year long at a constant rate. Therefore in summer time too much gas is pumped up that is stored in empty gas fields and salt caverns for use in winter time. About 18% of total gas demand is first stored before it is consumed in the EU, seeTimmerberg, Sebastian, and Martin Kaltschmitt. “Hydrogen from renewables: Supply from North Africa to Central Europe as blend in existing pipelines - Potentials and costs.” Applied Energy 237, 2019: 795-809. In future sustainable energy systems this seasonal storage needs to be dealt with.	Taken into Account. The figure has been removed.	Ad van Wijk	Technical University Delft	Netherlands
10133	7	23	9	3	Chapter 6.2 Elements of Energy Systems, the physical energy system as depicted in Figure 6.2 has some fundamental omissions and mistakes. 2. The transport and infrastructure capacities and connected cost (the amount of energy that can be transported per unit of time, expressed in f.e. GW) are ignored in the describtion of the physical system. Pipeline transport capacities for oil, gas, etc. have much larger capacities that electricity gird transport capacities. As an example gas pipeline transport capacities are between 15-30 GW, while Electricity transport capacities are between 1-2 GW. And the cost per unit energy for gas by pipelines is a factor of 10-20 cheaper than the cost of energy transport by an electricity transport grid. In future energy systems where good renewable energy resources are located far from the demand centres, f.e. solar in dessert areas and offshore wind, energy transport cost can not be ignored.	Same as 10131	Ad van Wijk	Technical University Delft	Netherlands
10135	7	23	9	3	Chapter 6.2 Elements of Energy Systems, the physical energy system as depicted in Figure 6.2 has some fundamental omissions and mistakes. 3. Large scale multi GW solar and wind production offshore and in dessert areas will directly at the site of these solar and wind farms be converted to hydrogen that can be transported as a gas by pipelines or converted into liquid hydrogen, ammonia, methanol or in another fuel and then be transported all around the world by ship. So these multi GW solar and wind farms are not or minimally connected to the electricity grid. In figure 6.2 power to gas conversion units are directly coupled to the electricity grid, whereby it seems that hydrogen is converted back to methane to be fed into a natural gas grid. As explained above, this has no logics, the electricity grid has a much smaller capacity than a gas grid and is more expensive. Also conversion from hydrogen to methane has no logics, where do get the Carbon or Carbonmonoxide in a decarbonized energy system. Besides hydrogen can be transported through the natural gas pipelines, with only minor adaptations. In several reports the role of hydrogen as an energy carrier for large scale transport and storage and for deep decarbonization of feedstock and energy use in industry, for energy use in transport and buildings and for electricity balancing is explained . See the Hydrogen Council report ''How Hydrogen empowers the energy transition'' https://hydrogencouncil.com/wp-content/uploads/2017/06/Hydrogen-Council-Vision-Document.pdf and the IEA report The future of hydrogen https://www.iea.org/reports/the-future-of-hydrogen and the book "Solar Power to the People" https://www.alliedwaters.com/wp-content/uploads/2017/11/Solar-Power-to-the-People-EN.pdf	Same as 10131	Ad van Wijk	Technical University Delft	Netherlands

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
10137	7	23	9	3	Chapter 6.2 Elements of Energy Systems, the physical energy system as depicted in Figure 6.2 has some fundamental omissions and mistakes. 4 Fuel cell and electrolysis technologies are electro-chemical conversion technologies that will become very important in a future sustainable energy systems. Low temperature fuel cells, e.g. the PEM fuel cell will become an important technology for mobility in larger cars, busses, trucks, boats, trains, drones and eventually airplanes. But the PEM fuel cell will become also important for electricity balancing and as cogeneration plants, producing both electricity and heat for buildings and houses, supplementing electricity production by solar PV. Mass production can bring down stack cost to less than $50/kW, with full load efficiencies of over 60% and part load efficiencies going up to over 70% efficiency, see f.e. US DOE https://www.hydrogen.energy.gov/pdfs/review19/fc163_james_2019_o.pdf. High temperature fuel cells, e.g. the Solid Oxide Fuel Cell, can produce from any fuel (ammonia,methanol,etc.) electricity but also mixtures of electricity and hydrogen. The reversible technology is the electrolyser technology, that use electricity to split water into hydrogen and oxygen. Different types of electrolysers are alkaline (a mature technology already in use for over 100 years but to produce chlorine from salt), PEM and SOEC. Present day efficiencies of alkaline electrolysers are over 80% at HHV, see Thyssen Krupp electrolysers https://d2zo35mdb530wx.cloudfront.net/_binary/UCPthyssenkruppBAISUhdeChlorineEngineers/en/products/water-electrolysis-hydrogen-production/alkaline-water-electrolysis/link-thyssenkrupp_Hydrogen_Water_Electrolysis_and_green_chemicals.pdf. Cost today for a 100 MW system are Euro 400/kW and will come down to about Euro 200/kW for GW systems in 10-20 years, see f.e. https://www.bloomberg.com/news/articles/2019-08-21/cost-of-hydrogen-from-renewables-to-plummet-next-decade-bnef	Same as 10131	Ad van Wijk	Technical University Delft	Netherlands
46075	7	23	19	26	why only linear energy system is shown, no integration of power, heating, cooling, transport, water and mobility energy systems through power-to-X technologies?	Accepted. We are working to revise this figure	Neven Duic	University of Zagreb	Croatia
29985	7	25	7	25	"include" should be "includes"	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Brett Cohen	The Green House consultants	South Africa
29987	7	27	7	27	Consider an alternative word to "outsized".	Accepted	Brett Cohen	The Green House consultants	South Africa
15041	7	32	7	32	The more complex approach of J.S.Norgaard (1998) (Sustainable Energy Future - Nordic Perspective, Figure 1) shows important connections to social science as well. http://inforse.org/europe/word_docs/s_jn_fut.doc	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Béla Munkácsy	ELTE University	Hungary
23907	7	32	7	32	Figure 6.1. ithe systems could be called, as described in the figure titel, physical, instotutional, social system. Also an interaction of the energy system with other system could be shown, e.g. the environment, market, etc., showing that it is not an isolated system.	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Stefan Majer	German Biomass Research Centre - DBFZ	Germany
5205	7	32	7	33	Figure 6.1 should more distinctively reveal the difference between renewable and non-renewable energy sources.	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Andreas Oberheitmann	FOM University of Applied Sciences	Germany
15569	7	32	7	33	Figiure 6.1 is rather the Energy Sector	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Joseph Essandoh-Yeddu	Energy Commission	Ghana
34189	7	32	7	33	what does the graph mean ?	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Antoine BONDUELLE	Climate Action Network France	France
15571	7	32			The physical energy system is rather the Energy System	Rejected. It is the perspective of this chapter that the energy system goes beyond the physical system.	Joseph Essandoh-Yeddu	Energy Commission	Ghana
16951	7	33	7	33	I did not agree with the hierachical structure in Figure 6.1, I think society is within energy system, as well as institutions. Energy system is the phisical basis for all of it. Maybe another form will illustrate it better. Another problem is, disposal process (recycle and reuse) should be mentioned in Figure 6.1. I also suggest include some illustration or explaination of disposal phase in a energy system in this chapter, considerring the disposal of battary, wind turbines, even coal-fired power plant and so on, are very important issues in a sociaty with rapidly devoloping energy technologies.	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Qing YANG	Harvard University	China
45151	7	33	7	33	Energy systems also interact within an environmental realm that is not captured by the (1) physical energy system (2) institutions, laws and regulations and (3) society depiction in Figure 6.1. Important aspects of the energy-water-food-climate nexus would be represented with an environmental realm. The impacts of physical energy systems with the environment also need to be depicted. The performance of all elements determines the level of impacts and interaction with the environment. This will also be important to support the existing emphasis on the SDGs within the chapter.	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Siir Kilkis	The Scientific and Technological Research Council of Turkey	Turkey
2121	7	33			I'm not sure how useful this figure is. The concepts are explained well in the text. The chapter is very long so it could be deleted	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Amy Townsend-Small	University of Cincinnati	United States of America
148	7		10		Section 6.2 Elements of Energy Systems refers to Electrical Energy Systems. The topic of 6.2 should be Elements of Electrical Energy Systems.	Rejected. This chapter is not just about electricity. It is about the full energy system, of which electricity is only a part.	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
33245	7		10		In this chapter you should introduce the question of ressource/reserve and the concept of EROEI which is esential for resilience. Furthermore, energy system needs ressources to be developed such as cement, steel, rare earth…. And they have wastes of different characteristics. These elements are key for SD, then to evaluate potential pathways.	Taken into Account. EROI is addressed variously throughout the chapter, although there is no specific section on it. For example, the fossil section explicitly discuss EROI, and the wind section disucsses the carbon payoff time for wind turbines, which is roughly correlated with EROI. We will revisit this issues following comments on the SOD.	Marc Darras	Association 4D	France
45419	7				Section 6.2 has good points, however it can be made a lot more concise; it can be made a lot less abstract by citing specific cases. The section provides many generalizations, but it will be much clearer to the reader if examples are cited. For example, what is an example of energy system dynamics linked to geopolitical issues associated with ownership of resources?	Accepted. We are substantially shortening this section.	Girija Parthasarathy	Thermo King	United States of America
39803	8	4	8	4	various systems' should be 'various sub-systems'	Accepted	Debadutta Mohanty	CSIR-Central Institute of Mining and Fuel Research	India
19821	8	4	8	6	In addition to basic services and consumer products, energy is also need for production of food (growing and harvesting crops), production of raw materials (such as cotton crops), manufacturing, mining and construction.	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Ghulam Rasul Athar	Pakistan Atomic Energy Commission	Pakistan
18663	8	5	8	5	consider a change from 'as well as for consumer products' to 'as well as for consumer products and for commercial and industrial activities'	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
45709	8	5	8	6	this sentence is repeted at line 27-29	Accepted. The section is being substantially shortened.	anna maria sempreviva	Wind Energy Department, Technical University of Denmark, Roskilde	Denmark
144	8	6	8	7	..are the reasonS...	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
26583	8	6	8	7	Air pollution also results from heat production, particularly in cities.	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Peter North	Calorem Ltd, Imperial College (part-time PhD student)	United Kingdom (of Great Britain and Northern Ireland)
6337	8	6	8	8	the sentence 'Air pollution that can result from electricity production in the physical energy systems interacts...' might steer the reader toward understanding that ONLY the pollution from electricity production is of concern or relevant'. Emissions from heating and industrial systems (which are part of the definition of energy system) exceed the one from electricity only. Please rephrase the sentence mentioning also the other subsectors main contributors to air pollution/CO2 emissions	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Sciacovelli Adriano	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
19823	8	6	8	8	Air pollution is not only happened from electricity production but almost from each step of every energy chain. Furthermore, air pollution resulting from electricity production is not the only driver for energy system change but it is true in other sectors also for example, cooking, and transportation.	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Ghulam Rasul Athar	Pakistan Atomic Energy Commission	Pakistan
29989	8	10	8	10	Consider an alternative word to "outsized".	Accepted	Brett Cohen	The Green House consultants	South Africa
146	8	13	8	14	Linear pathway or Unidirectional pathway? I believe that it should be unidirectional pathway.	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
26585	8	13	8	20	There is an emerging interest in reuse (building heating), i.e., moving away from the linear pathway to a circular pathway for city heating.	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Peter North	Calorem Ltd, Imperial College (part-time PhD student)	United Kingdom (of Great Britain and Northern Ireland)
19825	8	15	8	15	Prospection/exploration may be added before or after ‘energy resources’	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Ghulam Rasul Athar	Pakistan Atomic Energy Commission	Pakistan
19827	8	16	8	17	Hydro is missing in energy sources	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Ghulam Rasul Athar	Pakistan Atomic Energy Commission	Pakistan
28439	8	17	8	17	better replace "tidal energy" with "marine renewable energy"	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Matt Lewis	Bangor University	United Kingdom (of Great Britain and Northern Ireland)
6339	8	18	8	18	Does energy transformation here means energy conversion? please make sure conversion/transformation are used properly	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Sciacovelli Adriano	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
39141	8	19	8	30	need to clearly define the difference beyween the energy carriers and the energy if there is a difference in the cpncept of energy carriers and energy. Need to define in what step the energy carriers is converted to energy	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Dong-Woon NOH	Korea Energy Economics Institute	Republic of Korea
6449	8	20	8	20	electricity is no gaseous fuel!	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Paul Neetzow	Humboldt-Universität zu Berlin	Germany
14437	8	20	8	20	"[E]lectricity" is not a "gaseous fuel[]".	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Jean-Sébastien Landry	Environment and Climate Change Canada	Canada

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
19569	8	20	8	20	electricity should not to be gaseous fuels	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	China
19829	8	20	8	20	Electricity is not a gaseous fuel	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Ghulam Rasul Athar	Pakistan Atomic Energy Commission	Pakistan
29991	8	20	8	20	Reconsider including electricity as a "gaseous fuel".	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Brett Cohen	The Green House consultants	South Africa
34143	8	20	8	20	Electricity is a gaseous fuel ? Might be clearer to put electicity separetely [suggestion ENSEEIHT INP]	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Antoine BONDUELLE	Climate Action Network France	France
36709	8	20	8	20	Electricity is not a gas. I suggest to write: "...or jet fuel), gaseous fuels (e.g., methane and hydrogen) and electricity."	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Pietro Altermatt	R&D Center of Trinasolar	Germany
39805	8	20	8	20	how 'electricity' could be a gaseous fuel? This should be deleted	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Debadutta Mohanty	CSIR-Central Institute of Mining and Fuel Research	India
36337	8	20			How electricity can be considered as a gaseous fuel?	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Youba Sokona	South Centre	Switzerland
45423	8	20			Electricity is not a gaseous fuel! Electricity is another energy carrier.	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Girija Parthasarathy	Thermo King	United States of America
1625	8	22	6	22	Should be: 'from the ground' or 'from under ground'	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Jenkins Rhosanna	University of East Anglia	United Kingdom (of Great Britain and Northern Ireland)
29993	8	22	8	22	Remove the word "the" before "underground"	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Brett Cohen	The Green House consultants	South Africa
19831	8	23	8	23	'must be' may be changed to 'are'	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Ghulam Rasul Athar	Pakistan Atomic Energy Commission	Pakistan
19833	8	23	8	23	'any range' may be changed to 'a range'	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Ghulam Rasul Athar	Pakistan Atomic Energy Commission	Pakistan
10077	8	25			I would not say that concentrating solar power is a 'direct' conversion from solar energy to electricity. Maybe they should be mentioned before the word direct to avoid that ssumption.	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Maria E. Mondejar	Technical University of Denmark	Sweden
31779	8	27	8	30	The energy services provided should also support various non-household uses (perhaps to eventually benefit households) - this includes agriculture, commercial services, industry etc.	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Ashok Sreenivas	Prayas (Energy Group)	India
45711	8	27	8	30	this part reads trivial	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	anna maria sempreviva	Wind Energy Department, Technical University of Denmark, Roskilde	Denmark
19835	8	29	8	29	to clean..?'. A word is needed after 'to clean ' such as environment, house...	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Ghulam Rasul Athar	Pakistan Atomic Energy Commission	Pakistan
16659	8		9		Figure 6-2. Heat transport networks are missing. Thanks to physical laws, fosssil and nuclear power plants are powerful heat sources for e.g. district heating..	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Jean Louis Bobin	Sorbonne universités Paris	France
14439	9	0	9	0	Chapter numbers in Figure 6.2 are not the good ones.	Taken into Account. The figured has been removed, as it seemd to be adding little beyond AR5.	Jean-Sébastien Landry	Environment and Climate Change Canada	Canada
5207	9	1	9	1	Figure 6.2 should (a) also include briquette production, heat plants and combined heat and power generation in the conversion section, and (b) include the contribution of CCS on enhanced oil and gas revovery. In the text, non-energy use, e.g. mineral oil as feedstock in chemical industry, should be explicitely mentioned before introducing physical energy systems.	Taken into Account. The figured has been removed, as it seemd to be adding little beyond AR5.	Andreas Oberheitmann	FOM University of Applied Sciences	Germany
6341	9	1	9	1	The figures implies that demand is only supplied with either electricity or fuels. However, buildings/cities/industries in multiple counties are supplied directly with thermal energy, for example through district heating network that connect CHP plants or Geothermal Plants with demand. the figure should be modified to account also for thermal energy vector	Taken into Account. The figured has been removed, as it seemd to be adding little beyond AR5.	Sciacovelli Adriano	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
13829	9	1	9	1	Figure 6.2 : If the goal is to have an exhaustive figure, tidal and wave energy sources are missing (different from others presented)	Taken into Account. The figured has been removed, as it seemd to be adding little beyond AR5.	Alexandre Bizeul	International Energy Agency	France
28441	9	1	9	1	figure 6.2 ought to be updated to potential pathways - including shipping electrification and including marine renewables	Taken into Account. The figured has been removed, as it seemd to be adding little beyond AR5.	Matt Lewis	Bangor University	United Kingdom (of Great Britain and Northern Ireland)
45359	9	1	9	1	Placement of storage in image is too specific - much new storage is either at the generations site (especially renewaables), not mid transmission grid. Recommend adding similar icon to right of the generation plants and labelligh one as On-site energy storeage and the other as On-grid energy storage	Taken into Account. The figured has been removed, as it seemd to be adding little beyond AR5.	Deborah Knuckey	Published energy journalist plus consultant for renewable energy development and finance companies through Kiterocket	United States of America

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
46077	9	1	9	1	No heating networks, no power-to-heat, no vehicle-to-grid, no waste to heat from industry	Taken into Account. The figured has been removed, as it seemd to be adding little beyond AR5.	Neven Duic	University of Zagreb	Croatia
36703	9	1	9	2	Power to Gas should also appear directly next to Wind and Solar plants, not only after up- and down-tranforming.	Taken into Account. The figured has been removed, as it seemd to be adding little beyond AR5.	Pietro Altermatt	R&D Center of Trinasolar	Germany
36705	9	1	9	2	Storage should also appear directly next to solar plant and wind plant, before the electric power grid, as large amounts of small scale storage is becoming economically feasible.	Taken into Account. The figured has been removed, as it seemd to be adding little beyond AR5.	Pietro Altermatt	R&D Center of Trinasolar	Germany
36707	9	1	9	2	Figure 6.2 from Bruckner et al. 2014 is outdated and does not reflect the progress made in integrated assessment modeling.	Taken into Account. The figured has been removed, as it seemd to be adding little beyond AR5.	Pietro Altermatt	R&D Center of Trinasolar	Germany
45153	9	1	9	2	Although a placeholder for the SOD, it will be important for Figure 6.2 to at least include referral to urban energy systems on the right hand side with an explicit indication of Chapter 8.	Taken into Account. The figured has been removed, as it seemd to be adding little beyond AR5.	Siir Kilkis	The Scientific and Technological Research Council of Turkey	Turkey
15577	9	1			Figure 6.2. Where does one place Wave Power / Ocean Wave / OTEC and Hydrogen? We need to incorporate it into the figure. Secondly, the title rather could just read "Overview of the Energy System".	Taken into Account. The figured has been removed, as it seemd to be adding little beyond AR5.	Joseph Essandoh-Yeddu	Energy Commission	Ghana
19571	9	1			Heat is absent in the physical energy system in Figure 6.2.	Taken into Account. The figured has been removed, as it seemd to be adding little beyond AR5.	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	China
20337	9	2			Fig. 6.2 documents major deficits in modern energy systems. I miss any Power-to-X route for fuels. It is simply missing, but biofuels are displayed. Fasihi et al. (https://www.sciencedirect.com/science/article/pii/S1876610216310761) describe Power-to-fuels. CO2 DAC for DACCU/PtX is not displayed, but nowadays a standard component in energy transition studies, see for instance Osorio-Aravena et al. (https://journals.aau.dk/index.php/sepm/article/view/3385)	Taken into Account. The figured has been removed, as it seemd to be adding little beyond AR5.	Christian Breyer	LUT University	Finland
18665	9	4	9	4	The physical characteristics of an energy system do not define its operation'. This could perhaps be better phrased as the physical charactersistics of an energy system are fundamental in defining its operation. An energy system cannot operate outside of its physical characterstics. I completely agree with the wider point that the system is governed by rules and regulations - but these themselves are based on the physical characteristics of the energy system. Different characteristics have different rules e.g. the rules and regulations that govern the electrical, natural gas or liquid fuel systems are framed by the underpinning characteristics of each.	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
37367	9	4	9	4	The sentence is inaccurate - it is correct to say that the physical characteristics of a system are not the only determinant of their operation, but incorrect to say that they do not determine the operation of the system	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Michiel Schaeffer	Climate Analytics	Netherlands
37369	9	4	10	5	The framing of these two paragraphs ignores the influence of technical limitations on energy demand and supply	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Michiel Schaeffer	Climate Analytics	Netherlands
14443	9	6	9	7	Readers may not understand what "rules for dispatching electricity generation technologies". Consider replacing with something like "rules for the real-time dispatch of individual electricity generation units".	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Jean-Sébastien Landry	Environment and Climate Change Canada	Canada
45705	9	16	9	18	I would write "is meant for e.g." instead of "meant to produce, for example" and "mobility" instead of "Transportation."	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	anna maria sempreviva	Wind Energy Department, Technical University of Denmark, Roskilde	Denmark
16661	9	16			A:mong other actors, governments, lobbies, NGO shoulb be explicitely quated. The judiciary is often enacted in order to settle environmental conflicts abou energy systems.	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Jean Louis Bobin	Sorbonne universités Paris	France
19837	9		9		In Primary Energy, 'Nuclear Energy' may be changed to 'Nuclear Fuel' or 'Uranium' like other energy carriers, Crude oil, Coal and Natural Gas.	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Ghulam Rasul Athar	Pakistan Atomic Energy Commission	Pakistan
19839	9		9		Cokery is generally for converting coal to coke to be used in steel industry. However, steam coal is also being used in industry. There a direct transport link is needed from Coal at Primary Level to Industry at Final level to correct representation of use of steam coal in Industry. Otherwise rename the 'Cokery' to 'Cokery/Coal Cleaning'.	Taken into Account. The figured has been removed, as it seemd to be adding little beyond AR5.	Ghulam Rasul Athar	Pakistan Atomic Energy Commission	Pakistan
19841	9		9		'Electric Power Station' may be renamed as 'Fossil based Power Station' as other power plants are named on their fuels, i.e., Nuclear Power Plant, Hydro Power Plant…	Taken into Account. The figured has been removed, as it seemd to be adding little beyond AR5.	Ghulam Rasul Athar	Pakistan Atomic Energy Commission	Pakistan
19843	9		9		'Gas Transport' between Secondary Energy Level and Final Energy Level is not needed. Either a conversion technology may be added such as 'Gas Processing' at Secondary Energy Level or transport gas directly from Primary Energy Level to Final Energy Level.	Taken into Account. The figured has been removed, as it seemd to be adding little beyond AR5.	Ghulam Rasul Athar	Pakistan Atomic Energy Commission	Pakistan
19845	9		9		Caption 'Chapter 7 on Energy System' may be deleted. Also need to change Chapters numbers mentioned in Figure according to current version of the report.	Taken into Account. The figured has been removed, as it seemd to be adding little beyond AR5.	Ghulam Rasul Athar	Pakistan Atomic Energy Commission	Pakistan
34145	9		9		Transport needed for nuclear energy not indicated in figure [suggestion ENSEEIHT INP]	Taken into Account. The figured has been removed, as it seemd to be adding little beyond AR5.	Antoine BONDUELLE	Climate Action Network France	France

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33243	9				Figure 6.2 for gas system, you make a difference for the flow of "power to gas" and for biogas, which is identical in itself; you do not mention hydrogen, the first power plant square should be named "Conventional thermal power plant" beacuase all power plant are electric PP. You have a block with "transformer" which is unclear in this position, and you could simplify to have only one Electric power grid. Gas transport implies ships for LNG.	Taken into Account. The figured has been removed, as it seemd to be adding little beyond AR5.	Marc Darras	Association 4D	France
42351	9				You don't need the "Electric Power grid" block right after power plants. The one after storage is suitable and sufficient.	Taken into Account. The figured has been removed, as it seemd to be adding little beyond AR5.	Solomon Asfaw	LUT University	Finland
45703	9				Figure 6.2. Fuzzy	Taken into Account. The figured has been removed, as it seemd to be adding little beyond AR5.	anna maria sempreviva	Wind Energy Department, Technical University of Denmark, Roskilde	Denmark
5209	10	1	10	1	One basis that should be mentioned for the establishment of rules are district energy policies of the government. E.g. phasing out nuclear energy in Germany.	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Andreas Oberheitmann	FOM University of Applied Sciences	Germany
15573	10	1	10	6	Rather a description of an Energy Sector	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Joseph Essandoh-Yeddu	Energy Commission	Ghana
37371	10	6	10	13	Substitute for the word 'outsized' to capture the required connotation	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Michiel Schaeffer	Climate Analytics	Netherlands
2123	10	18			there are similar grids of pipelines for natural gas and petroleum products!	Accepted. Lines 17-21 will be rewritten	Amy Townsend-Small	University of Cincinnati	United States of America
18667	10	19	10	20	Natural gas, oil, and coal are all transported long distances across national borders on land and over water' - This is true, but could be rephrased as it gives the impression the majority of these resources are traded internationally, which is not necessarily the case. consider 'Natural gas, oil, and coal are traded as commodoties and can be transported long distances across national borders on land and over water'	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
23909	10	26	10	26	why only the physical energy system is written later on with "bold" ?	Noted. This material has been removed as part of an effort to shorten 6.2 in line with several comments	Stefan Majer	German Biomass Research Centre - DBFZ	Germany
45713	10	28			Section 6.3. In the introduction,at page 6 it is stated that each question corresponds to a different section. However, here, the question is splitted in two questions. Different trends are presented according to question 1) and this is good. But question 2 is not really answered. In short, section 6.3 needs to be structured according to aspects and themes.	Section 63 has been amended. For instance new paragr on drivers (kaya decomposition). Some restructuring of the paragraphs. However headings will be kept.	anna maria sempreviva	Wind Energy Department, Technical University of Denmark, Roskilde	Denmark
184	10	33	10	33	....are considered in other "sections" of this chapter.	Accepted. Replace chapters by sections	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
154	10	33			....are considered in other "sections" of this chapter.	Accepted. Chapters will be replaced by sections	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
23911	10	34	10	34	6.3.1. the previously introduced layers of the energy system are not followed later on? At least a comment could be introduced, which parts of the energy system are concidered, when describing e.g. the emissions, etc. Titel could include "global"	Accepted. Definition on boundaries energy systems in the introduction of 6.3. Fig 6.2 amended to better show energy systems boundaries	Stefan Majer	German Biomass Research Centre - DBFZ	Germany
17697	10	35	10	36	Same point as made for the Exec Sum - which current trends and how extrapolated	add between bracket (table 6.1)	Michael Grubb	UCL - Institute of Sustainable Resources	United Kingdom (of Great Britain and Northern Ireland)
150	10	35	10	45	Figure 6.3 and Figure 6.4 are not explained or cited in the text.	New figures 63 and 64	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
11349	10	35	23	2	Note: 1. India's latest communication deals with year 2014 (Base year). Then India's emission numbers for 2016-2018, which have been taken into account are not the officially declared number communicated by Govt. of India. Similar case may be there for other countries. Therefore global estimates and trends of last few years may be stated as provisional in the foot note. Note 2. In spite of 'Power for all policy' Govt. of India has restricted the growth of conventional coal based power generation to 3. 57% as compared to 5.64% in 2015-16 and promoted the growth of renewable generation to 24.47% as compared to 6.47% in 2015-16 (Ref: https://powermin.nic.in/en/content/overview)	All emissions for India and other countries from IEA or EDGAR for consistency	PINAKI SARKAR	CSIR-CENTRAL INSTITUTE OF MINING AND FUEL RESEARCH	India
1127	10	35			Provide reference	IPCC, 2018: Summary for Policymakers. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty	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
33247	10	35			The boundary of the system you consider is defferent from figure 6.2. For clarification youd should mention "Current trends of the global emission of energy system and consumption..."	Accepted. We shall mention the whole energy system or supply and demand. A definition is also included at the beginning to make the boundary very clear. Figure 6.2 will also be amended and commented to clearly define the boundaries between emissions from the whole energy system and emissions limited to energy supply. A new input added regarding emissions with a focus on energy supply.	Marc Darras	Association 4D	France
1129	10	37	10	39	Provide reference	Reference is provided. Ensure it is clear enough.	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
5873	10	37		41	References missing. Or is all this data from Crippa et al? Can update some of the stats quoted eg https://www.iea.org/articles/global-co2-emissions-in-2019?utm_campaign=IEA%20newsletters&utm_source=SendGrid&utm_medium=Email	All reference for data consistency from Crippa et al as mentioned. Data will be updated	Ralph Sims	Massey University	New Zealand
36339	10	38			here it should 37.8 Gt in 2018 and not 37.8 Gt/yr	Accepted and amended.	Youba Sokona	South Centre	Switzerland
6025	10	39	12	2	The statistical descriptions in the paragraphs does not correlate clearly with the presented figures and tables. Reader has as difficult time to digest the statistical information in the corresponding paragraphs while referring to the figures or tables. Reference to specific Figure 6.xx shall be clarified instead of just Figure 6. in the corresponding paragraphs	Accepted. Text and figures will match and reading should be easier.	SAIK PENG, CASEY NGO	R-SYNC TECHNICAL RESOURCES SDN. BHD.	Malaysia
186	10	41	10	41	Figures 6. refers to which Figure?	Accepted. All number figures will be revised.	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
156	10	41			Figures 6. refers to which Figure?	Accepted. All number figures willl be r evised.	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
19573	10	41			"(see Figure 6.)" number of the Figure is missing	Accepted	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	China
31391	10	43	10	43	What about a reference for the coal hypothesis? Or referring to the corresponding chapter.	Amended and reformulated. CO2 emissions are presented for all energy sources not only coal.	Patrick Jochem	German Aerospace Center (DLR)	Germany
1133	10	43			Please be more precise on the statement "However, per capita CO2 emissions in these countries still remain well below developed countries." Specially put numbers in stead of "well below"; also a definition of developed countries is needed; China has the 2nd largest GDP; in terms of total GDP it is more developed than any other country except USA - but that does not mean China has a very high GDP per capita as well; so a definition of developed countries is needed; or else you can replace it with countries with a certain GDP per capita or else OECD countries	Rejected. There is already a table on emissions per capita. However, space permitting, we can add a few lines on emissions per capita and countries for main countries. There is a glossary for defintion	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
2125	10	43			I would add something to this sentence to make it clear that most developed countries still rely on fossil fuel for both electricity and transportation, although they may have made progress towards reducing their reliance on coal	Amended. New paragraph. See comment line 11	Amy Townsend-Small	University of Cincinnati	United States of America
11345	10	44	10	45	about 'emission from coal generation' - It should be 'emission from coal based electricity generation'.	Accepted. Will be amended	PINAKI SARKAR	CSIR-CENTRAL INSTITUTE OF MINING AND FUEL RESEARCH	India
13831	10	44	10	45	Emissions from coal are closest to 15 Gt than 10 Gt mentioned (14.502 Gt in 2017 source IEA CO2 emissions from fuel combustion, 2019 : https://www.iea.org/data-and-statistics?country=WORLD&fuel=CO2%20emissions&indicator=CO2%20emissions%20by%20energy%20source) . Maybe it is emissions from "coal power generation" instead of "coal generation" ?	Accepted.Amended and reformulated. CO2 emissions are presented for all energy sources not only coal.	Alexandre Bizeul	International Energy Agency	France
19577	10	44	10	45	what is the data source to support this? the latest data in IEA WEO2018 is the data in 2017	Accepted. Figures were revised updated and inserted in SOD	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	China
37373	10	44	10	45	There is a newer source from the same organisation (IEA 2019), which indicates that coal emissions declined by 0.2 Gt or 1.3% from 2018 levels.	Amended and reformulated. CO2 emissions are presented for all energy sources not only coal.	Michiel Schaeffer	Climate Analytics	Netherlands
1131	10	44			Provide reference in "Coal was the single largest contributor the growth in emissions between 2017 and 2018"	Amended. New paragraph. See comment line 11	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
19575	10	44			"coal generation" coal-fired power generation?	Accepted and amended	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	France
44375	10	44			typo: "contributor the growth" should be "contrubutor to the growth"	Accepted and amended	Pietro Guarato	University of Lausanne	Switzerland
188	10	45	10	45	GtCO2 in 2018, "increased" by 2.9 % from 2017 to 2018.	Noted. Editorial. We may keep the same wording	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
6253	10	45	10	45	The citation of the Figure is as (Figure 6.). There is a need for proper citation that is (Figure 6.3).	Accepted. All number figures will be revised.	Brown Gwambene	Marian University College	United Republic of Tanzania

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
11347	10	45	10	45	About Fig 6. Would it be Fig. 6.4?- please check	Accepted. All number figures will be revised	PINAKI SARKAR	CSIR-CENTRAL INSTITUTE OF MINING AND FUEL RESEARCH	India
158	10	45			GtCO2 in 2018, "increased" by 2.9 % from 2017 to 2018.	Rejected. However this parag will be reformulated	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
19579	10	45			“(Figure 6.)” number of the Figure is missing	Accepted. All number figures will be checked and amended accordingly	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	China
20243	10		15		The coronavirus outbreak in 2020 may lead to the reduction in energy consumption due to temporaly shut down of factories and restriction of aviation . Therefore, the energy trend and development should be updated.	Accepted. Addressed. Section on corona	Thi Lan Huong Huynh	Viet Nam Institute of Meteorology, Hydrology and Climate change	Vietnam
190	11	2	11	2	Define GtCO2, tCO2/Cap/Year and tCO2/KUSD/year on Table 6.	Rejected. Metrics already defined. No need to define here. Ensure KUSD if it part of the metrics	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
6255	11	2	11	2	Figure 6.3 and Figure 6.4 are not cited in the main text.	Accepted. Figures are cited but incorrectly. All figures numbers will be revised	Brown Gwambene	Marian University College	United Republic of Tanzania
14445	11	2	11	2	Title of Table 6.1 does not fit with the content of the table.	Accepted. Title change. Provisional title could be key indicators of CO2 emissions. Furthermore table 6.1 is updated.	Jean-Sébastien Landry	Environment and Climate Change Canada	Canada
160	11	2			Define GtCO2, tCO2/Cap/Year and tCO2/KUSD/year on Table 6.	Metrics already defined. No need to define here. Ensure KUSD if it part of the metrics	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
1141	11	2			Fossil fuel, industrial processes and product use CO2 emissions should be included in column header	Noted. Table title changed to key indicators to match the content	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
19581	11	2			Table 6.1.the unit of "tCO2/kUSD/yr" may not need yr, should be "tCO2/kUSD"	Accepted	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	China
16955	11	4	11	5	Figure 6.3 should be improved in many aspects, at least 2 should be subscripted in CO2.	Accepted. Figure design has been revised. Further revisions not excluded. CO2 will be subscripted accross the whole chapter.	Qing YANG	Harvard University	China
6451	11	4	11	6	Figure does not look nice. Also, it takes a while to realize that changing rates are displayed instead of absolute values. Also, more past values would be informative.	Accepted. To make it clear this figure is now side by side with total CO2 emissions. Time horizon of figure 63 will be amended to match total emissions	Paul Neetzow	Humboldt-Universität zu Berlin	Germany
18669	11	9	12	1	Figure 6.4 and 6.5 - keep similar y-axis units - a general point to keep units the same where possible	Accepted. Similar units will be used for both, Mt CO2 . Figure 6.5 has been amended acordingly in SOD and new design. If chapter opts for Gt, figures will be amended accordingly.	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
5875	11	10		18	Are far better IEA figures available than this Fig 6.4 giving greater breakdown of emissions from all sources of primary energy. Transport discussion not linked to Chap 10. Is this transport detail needed here given this chapter should mainly involve heat and power systems.	Figure 6.4 has been amended and better figures provided	Ralph Sims	Massey University	New Zealand
24627	11	11	11	12	The power industry in Iran represents 29.3% of CO2 emmisions according to the last version of Energy balance sheet	Rejected. Figures are for the world and not Iran. Furthermore discrepancy between Iran and World for transport is coherent	Sanaz Jafarzadeh	Thermal Power Plants Holding Company	Iran
152	11	11	11	18	Figure 6.5 is not cited in the text.	Accepted although, it is cited as figure 6 p.11 line 12 This will be amended	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
6343	11	11	11	18	It is not unusual that in developed countries supply of heating (domestic and industrial) account for up to about 30% of CO2 emission. In this paragraph it should be mentioned that decarbonization of heating is also a key challenge for decarbonization	Accepted. Heating is better addresed across the whole chapter.	Sciacovelli Adriano	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
42943	11	11	12	2	This discussion is potentially misleading because it lacks precision, and it is also questionnnable. Most demand for energy worldwide is for heat and not for electricity (power), which does not seem to have been considered here. Also, it is for example stated: "The power industry is the largest single contributor to energy sector GHG emissions", representing 37% of the emissions, but the data shown in the figure refer to fossil energy carriers only.	Rejected.Power industry includes electricity and heat. We shall add between brackets (electricity and heat). Otherwise table is clear. Direct CO2 emissions from non fossil fuels are neligible.	Sigrid Kusch-Brandt	University of Padua	Germany
1135	11	11			Define what does it mean by "energy sector"? Include what other things are included in the "energy sector". A figure or table will represent better.	Accepted. Definition of energy sector has been added in 6.3 introduction. Fig 6.2 also amended to better define energy systems and its boundaries	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
12363	11	12	11	12	Please refer to Figure 6.5	Accepted	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
12877	11	12	11	12	Figure no. To be corrected to 6.5	Accepted	ASHOK NEMA	Nuclear Power Corporation of India Limited	India
10079	11	12			(Figure 6 .).-> Figure 6.5?	Accepted. fig 6.5 (amended)	Maria E. Mondejar	Technical University of Denmark	Sweden
19583	11	12			“(Figure 6.)” number of the Figure is missing	Accepted. Editorial	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	China
36711	11	14	11	16	This sentence is too vague and counter productive: "it is likely that petroleum products will remain the main fuels for road transport in most countries in the near future". I suggest to omit it. Where I work in China, half of employees come to work electrically, not with fossil fuel. And most visitors from abroad even don't realize this because it is so unpretentious.	It is written in most countries in the near future. We can add particularly poor countries given high cost of EV supply supply chain and particularly access to vehicles.	Pietro Altermatt	R&D Center of Trinasolar	Germany
37375	11	14	11	16	No justification/source for the argument that petroleum will remain the dominant transportation fuel. Please provide a citation or state that it is unknown the degree to which petroleum will remain dominant.	Accepted. It is written in most countries in the near future. We can however add particularly poor countries given high cost of EV supply supply chain and particularly access cost to electric evehicles.	Michiel Schaeffer	Climate Analytics	Netherlands
34147	11	14	11	17	Possible end of subsidies for electric cars in china may indicate downturn https://www.bloomberg.com/news/articles/2019-11-08/china-is-considering-cutting-electric-car-subsidies-again + while the amount of new electric vehicles is encouraging, it will take decades to replace the existing vehicle fleet [suggestion ENSEEIHT INP]	Accepted.Suggestion to be taken into consideration or reference to transport sector	Antoine BONDUELLE	Climate Action Network France	France
34191	11	14	11	17	Maybe this part is too optimistic, e.g. the possible end of subsidies for electric cars in china may indicate downturn https://www.bloomberg.com/news/articles/2019-11-08/china-is-considering-cutting-electric-car-subsidies-again. While the amount of new electric vehicles is encouraging, replacing the existing stock is tremendous: this is not emphasised enough in the text [suggestion ENSEEIHT INP]	Accepted. Split parag in two. Treat separately EV	Antoine BONDUELLE	Climate Action Network France	France
1137	11	14			Should be "total GHG emission" in stead of "total fossil fuel emission"	Accepted. GHG and not total fuel emissions. This will be checked across all 631 and 632 to ensure distinction between CO2 emissions and GHG emissions	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
1139	11	15			Mention the growth rate of electric vehicles from literature	Accepted. This will be added between brackets or cross ref transport sector	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
34149	11	18	11	18	Misleading not to speak about the fact that half of aviation’s climate impact is contrails https://www.atmos-chem-phys.net/19/8163/2019/. Could lead to minimize impact.[suggestion ENSEEIHT INP]	Rejected as it is not misleading. However we shall be looking at suggested reference	Antoine BONDUELLE	Climate Action Network France	France
3075	11				Table 6.1 does not include year 2018	Accepted. updated in SOD with 2018. Might be updated again if 2019 figures released ontime.	Ahmed Zobaa	Brunel University London	United Kingdom (of Great Britain and Northern Ireland)
36341	11				I wonder here if it is really /yr?	Rejected. No track of this comment here. However valid for previous comments	Youba Sokona	South Centre	Switzerland
45421	11				Figure references are not correct	Accepted. All figures numbers will be checked and amended accordingly.	Girija Parthasarathy	Thermo King	United States of America
36509	12	1	12	1	It seems to be used two data set for energy related CO2 emission, IEA’s WEO and Crippa’s report and there is a big gap among two data sets. It is better to use one of two statistics. When AR6 use IEA's data series, brakdwon are shwon at CO2 missin from Fuel combustion.	Partially accepted. Lines 2 to 5 will be amended to use same IPCC recommended database (Crippa). For CO2 emissions per source, IEA is used as Crippa does not provide emissions per source. Chapter 2 provides details on databases and boundaries.	Takashi Hongo	Mitsui & Co. Global Strategic Studies Institute	Japan
16957	12	1	12	2	Figure 6.5 should be improved in many aspects, at least 2 should be subscripted in CO2.	Noted. Fig 65 is limited to CO2 emissions by sectors	Qing YANG	Harvard University	China
2129	12	2			Is "buildings" another word for heating and cooking? I've wondered about this for a while	Rejected. There is a chapter on buildings.	Amy Townsend-Small	University of Cincinnati	United States of America
5877	12	2			Fig 6.5 shows buildings as well as power sector, so assume buildings is energy for heating but not stated. Also what are "other sectors"? Given they cover around 15% of CO2 emissions need to be identified - agriculture, fishing etc I assume.	All emissions from buildings not only heating. Building chapter will provide more detail. Others will be detailed if info available.	Ralph Sims	Massey University	New Zealand

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
32451	12	3	12	8	Because SLCPs are co-emitted with CO2 in energy production, transportation, and industry, CO2 mitigation measures will also reduce co-emitted non-CO2 climate forcers. CO2-targeted policies may be able to mitigate up to 70% of methane emissions and 30% of black carbon emissions. SLCP-targeted measures—like reducing methane from the agricultural sector and HFCs from cooling needs—are necessary for maximum benefit. Allen M., et al. (2018) TECHNICAL SUMMARY, in IPCC (2018) GLOBAL WARMING OF 1.5 ºC, 33–34; Shoemaker J. K., et al. (2013) What Role for Short-Lived Climate Pollutants in Mitigation Policy?, SCIENCE 342:1323–1324; and Rogelj J., et al. (2018) CHAPTER 2: MITIGATION PATHWAYS COMPATIBLE WITH 1.5 ºC IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT, in IPCC (2018) GLOBAL WARMING OF 1.5 ºC, 96; Xu Y. & Ramanathan V. (2017) Well below 2 °C: Mitigation strategies for avoiding dangerous to catastrophic climate changes, PROC. NAT'L. ACAD. SCI. 114(39):10315–10323 ("A fraction of CH4 (about 70%) and BC (about 30%) emissions can be mitigated through CO2-dedicated measures.").	Noted. Might be considered	Durwood Zaelke	Institute for Governance & Sustainable Development	United States of America
32793	12	3	12	8	Because SLCPs are co-emitted with CO2 in energy production, transportation, and industry, CO2 mitigation measures will also reduce co-emitted non-CO2 climate forcers. CO2-targeted policies can mitigate 70% of methane emissions and 30% of black carbon emissions. SLCP-targeted measures—like reducing methane from the agricultural sector and HFCs from cooling needs—are necessary for maximum benefit. Allen M., et al. (2018) TECHNICAL SUMMARY, in IPCC (2018) GLOBAL WARMING OF 1.5 ºC, 33–34; Shoemaker J. K., et al. (2013) What Role for Short-Lived Climate Pollutants in Mitigation Policy?, SCIENCE 342:1323–1324; and Rogelj J., et al. (2018) CHAPTER 2: MITIGATION PATHWAYS COMPATIBLE WITH 1.5 ºC IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT, in IPCC (2018) GLOBAL WARMING OF 1.5 ºC, 96; Xu Y. & Ramanathan V. (2017) Well below 2 °C: Mitigation strategies for avoiding dangerous to catastrophic climate changes, PROC. NAT'L. ACAD. SCI. 114(39):10315–10323.	Same as above. Repeated comment	Kristin Campbell	Institute for Governance & Sustainable Development	United States of America
1143	12	5			Provide reference	This figure will be updated and reference provided	A M Mabrur Ahmad Rashedi	Charles Darwin University	
192	12	7	12	7	Are non-GHG emissions as harmful as GHG emissions? What is the significance of non-GHG emissions?	Non GHG emissions beyond the scope of this chapter	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
12879	12	7	12	7	non-GHG emissions to be corrected as non CO2 GHG emissions	Accepted. will be amended to non CO2 emissions	ASHOK NEMA	Nuclear Power Corporation of India Limited	India
29087	12	7	12	7	Should this be non-CO2 emissions instead of non-GHG emissions?	Accepted. will be amended to non CO2 emissions. Same as above.	Minal Pathak	Ahmedabad University	India
162	12	7			Are non-GHG emissions as harmful as GHG emissions? What is the significance of non-GHG emissions?	Non GHG emissions beyond the scope of this chapter	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
2127	12	8			As natural gas use increases, methane emissions also increase even though CO2 emissions may decrease if it replaces coal.	Rejected. But this line is on bioenergy	Amy Townsend-Small	University of Cincinnati	United States of America
33249	12	8			Following this paragraphs which make a review of all emission, should we mention aerosols…., which are an element of the radiative forcing?	Beyond the scope of this chapter	Marc Darras	Association 4D	France
5211	12	9	12	9	After the Brexit, it is EU27 plus UK now.	Data provided is EU28 before Brexit. No change	Andreas Oberheitmann	FOM University of Applied Sciences	Germany
1145	12	9	12	10	The values are wrong; please put the correct data with references	This parag (lines 9 to 17) completely amended. It will be deleted and replaced by a new paragraph limited to energy systems and not the whole energy system	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
31781	12	9	12	17	This chapter's focus is perhaps more on flow of emissions and in that context, the various statistics presented here are perhaps valid. However, only stating that is likely to be misrepresented (and misused!). Hence, it would be good to have a paragraph somewhere about the role of emission stocks and the role of various countries in contributing to it.	Role of emissions stocks beyond scope of chapter 6.	Ashok Sreenivas	Prayas (Energy Group)	India
37377	12	9	12	17	It is unclear why this paragraph uses a source to identify high emitters, and then proceeds to only discuss emissions from developing countries.	This parag (lines 9 to 17) completely amended. It will be deleted and replaced by a new paragraph limited to energy systems and not the whole system	Michiel Schaeffer	Climate Analytics	Netherlands
38809	12	9			Please clarify which year "at present" refers to.	Accepted. However paragraph to be replaced and limited to energy supply	Julian Reyes	Personal Capacity	United States of America
19585	12	12	12	13	CO2 and GHG are mixed up	Same as comment line 60. This will be checked across all 631 and 632 to ensure distinction between CO2 emissions and GHG emissions	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	China
194	12	13	12	13	"lesser extent to India with respectively 52% and 12% of the total GHG emissions in the region." 52% and 12% refer to which countries?	This parag (lines 9 to 17) completely amended. It will be deleted and replaced by a new paragraph limited to energy systems and not the whole system	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
164	12	13			"lesser extent to India with respectively 52% and 12% of the total GHG emissions in the region." 52% and 12% refer to which countries?	Accepted. Parag to be rewritten	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
1627	12	14	12	14	I don't agree with the use of the word 'important' to describe the growth in China's emissions. If it really is important (rather than sizeable/substantial) I think this should be explained more.	Accepted as editorial. Will be considered	Jenkins Rhosanna	University of East Anglia	United Kingdom (of Great Britain and Northern Ireland)
196	12	17	12	17	We have the figure of 3.5% of GHG emissions in 2016. Do we have the latest figure? What are the percentages of GHG emissions in South Africa and North Africa?	This parag (lines 9 to 17) completely amended. It will be deleted and replaced by a new paragraph limited to energy systems and not the whole system. Latest figures provided	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
14447	12	17	12	17	"North Africa" is not a country.	Accepted and amended	Jean-Sébastien Landry	Environment and Climate Change Canada	Canada
166	12	17			We have the figure of 3.5% of GHG emissions in 2016. Do we have the latest figure? What are the percentages of GHG emissions in South Africa and North Africa?	Accepted. Will be updated and limited to energy supply. Percentages for South Africa and North Africa might be added	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
1147	12	17			There is no country named "North Africa". Could be North African countries.	Accepted	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
39133	12	18	12	18	change the 6.3.2 title to "Global primary energy supply and energy production continue to grow" and delete the energy consumption part(p. 14 line 6-14) since this section is about the energy supply and energy system(p. 10, line 32)	Accepted. Title might be changed to global energy supply and consumption continue to growth. Final energy consumption is not addressed in other chapters. Important to be captured for the whole report.	Dong-Woon NOH	Korea Energy Economics Institute	Republic of Korea
37379	12	19	12	23	The paragraph starts off by neutrally evaluating key disruptions to the energy system - however, the next sentence implicitly endorses them as mitigation options - this should not extend to shale gas (included in the first sentence), as the role of gas in Paris-compatible scenarios is distinctly unclear, especially with uncertainty around CCS availability (see AR6 WG3 FOD section 3.4.1).	Rejected. This pargraph is not controversial (high confidence) Furthermore there is cross ref to 6.7	Michiel Schaeffer	Climate Analytics	Netherlands
33251	12	19			The first global effect on the energy demand is the growth in asia, notably China and India. The impact of wind and solar remains small, even in the context or renewable if one considers biomass and hydro.	Comment not related to this line and following	Marc Darras	Association 4D	France
31393	12	24	12	24	I'm missing references here!	Accepted. Figures will be updated and ref (IEA, will be added)	Patrick Jochem	German Aerospace Center (DLR)	Germany
1149	12	25			Define "total primary energy supply"? e.g., Is it electrical energy or any other form of energy?	Rejected. There is a universal definiton of TPES. No need to be defined here. Space saving	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
45715	12	31	12	33	How small is the share of renewables? Should it not be quantified? If done later, it should be mentioned. Perhaps it should be mentioned that the future plan for offshore wind farms deployments in the North Sea	Accepted. A sentence o brackets might be added to show to share of RE	anna maria sempreviva	Wind Energy Department, Technical University of Denmark, Roskilde	Denmark
15135	12	31	12	35	Highly recommend mentioning hydropower, including share of hydro energy in 1971 and 2017	Accepted. Lines 31 to 35 to be amended	Aleksandr Kraevoy	UC RUSAL	Russian Federation
2131	12	31			What's the exact percent change in renewables over the last half century? This would be better than "substantial"	Accepted. We shall add between bracket (table 6.1) to be explicit or a reformulation.	Amy Townsend-Small	University of Cincinnati	United States of America
1151	12	32			State the share of renewable energy rather than mentioning "small". Put any relevant figure for better visualization.	Accepted same as above	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
198	12	33	12	33	The share of RE in the energy system today remains small. What is the percentage of RE in energy mix?	Same as comment 84. Sentence might be added or bracket	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
168	12	33			The share of RE in the energy system today remains small. What is the percentage of RE in energy mix?	Accepted same as above	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
8863	12	34	12	34	Current wording states that the share of nuclear is 1% of world energy supply. This figure should be documented, as it does not fit with other sources . In 2018, nuclear is around 4% of World energy supply, while wind and PV power is around 2.5%).	Accepted. Figures will be amended according to IEA world energy balance or another credible source	Michel SIMON	Vice Président SFENRAL	France
11119	12	34	12	34	The share of nuclear energy is 5% in 2016, 1% is the value of 1971.	Accepted. Figures will be amended according to IEA world energy balance	Midori Sasaki	industrial organization	Japan
13833	12	34	12	34	It seems that the share of nuclear power in total primary energy supply is 1% today vs 5% in 1971. Actually this is the opposite : 0.5 % (rounded to 1%) in 1971, 4.9% (rounded to 5%) in 2017. Suggestion : "The share of nuclear energy went only from 1% in 1971 up to a maximum of 7% in 2001 and 5% today (2017). Source : IEA Wrold energy balances 2019, accessible free of charge online : https://www.iea.org/data-and-statistics/data-tables?country=WORLD&energy=Balances&year=2017	Same as comment 88. will be updated and amended according to IEA world energy balance	Alexandre Bizeul	International Energy Agency	France
14449	12	34	12	34	"[S]hare of nuclear energy is just 1% against 5% in 1971". Fig. 6.6 shows the opposite, i.e. an increase in the share of nuclear energy between 1971 and 2016.	Same as comment 88 and 89. will be updated and amended according to IEA world energy balancend	Jean-Sébastien Landry	Environment and Climate Change Canada	Canada
18671	12	34	12	34	The share of nuclear energy is just 1% against 5% in 1971' - these values do not seem to be consistent with figure 6.6 on the following page	Same as comment 88. will be updated and amended according to IEA world energy balance	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
24313	12	34	12	34	The share of nuclear energy expressed in percentage hide the fact that it increased in absolute during the same period. It is a bit misleading. It is also strange to read this percentage their because it is the only one given this way in this section.	Same as comment 88. will be updated and amended according to IEA world energy balance	Alan BURLOT	Commissariat à l'énergie atomique et aux énergies alternatives	France

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
34197	12	34	12	34	Is the figure primary energy ? Is it global? No source given.	Accepted. Same as comment 88 to 92. Will be amended	Antoine BONDUELLE	Climate Action Network France	France
43565	12	34	12	34	”The share of nuclear energy is just 1% against 5% in 1971.” probably the other way round: 1% in 1971	Accepted. Same as comment 88 to 92. Will be amended	Adam Blazowski	FOTA4Climate.org	Poland
44759	12	34	12	34	”The share of nuclear energy is just 1% against 5% in 1971.” This is not correct, it seems to me that the numbers have been interchanged, i.e. 1% in 1971 and 5% now.	Accepted. Same as comment 88 to 92. Will be amended	Daniel Westlén	Liberal party Swedish parliament	Sweden
45411	12	34	12	34	"The share of nuclear energy is just 1% against 5% in 1971." I think this figure is incorrect, or at least ambiguous. Is it share of global primary energy? From IEA dat I find that nuclear is 4.4% of global primary energy in 2015, or 4.9% of primary energy in 2018 according to BP data.	Accepted. Figures revised, updated and amended in SOD according to latest IEA publication	Jessica Lovering	Carnegie Mellon University	United States of America
692	12	34	12	35	"The share of nuclear energy is just 1% against 5% in 1971.". It seems to be the opposite : It is now 5% agains less then 1% in 1971	Accepted. Same as comment 88 to 92. Will be amended	Francois-Marie Breon	CEA	France
35377	12	34	12	35	misspelling of "Fukushima"	Accepted. Same as comment 88 to 92. Will be amended	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France
35379	12	34	13	1	According to the reference synthesis World Nuclear Industry Status Report (Schneider, 2019), the decline of nuclear power had already begun before the Fukushima accident.	Fukushima is cited among other issues. A sentence might be added to reflect the comment.	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France
1153	12	34			Provide reference. One basic tenet of scientific writing is correct citation of previous works which strengthens the credibility of the underlying study.	Accepted. Same as comment 88 to 92. Will be amended and clearly referenced	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
19587	12	34			"The share of nuclear energy is just 1% against 5% in 1971". it was 1% in 1971, 5% in 2016 or 2017	Accepted. Same as comment 88 to 92. Will be amended and clearly referenced	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	China
19589	12	34			Figure 6.6 Total Primary Energy Supply may update to 2017	Accepted. Latest figures available will be used	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	China
33253	12	34			The share of nuclear power in TFC is 1,9% in 2017. AIE & BP statiscal review.	Accepted. Same as comment 88 to 92. Will be amended and clearly referenced	Marc Darras	Association 4D	France
44377	12	34			typo: "1% against 5%" should be "5% against 1%"	Accepted	Pietro Guarato	University of Lausanne	Switzerland
45425	12	34			The conclusion 'The share of nuclear energy is just 1% against 5% in 1971.' seems at odds with figure 6.7	Accepted. Links with previous comments.	Girija Parthasarathy	Thermo King	United States of America
200	12	35	12	35	.....causing many countries to adjust their nuclear.....	Accepted.	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
15045	12	35	12	35	Fukushima instead of Fukishima	Accepted	Béla Munkácsy	ELTE University	Hungary
43567	12	35	12	35	"Fukishima" should be Fukushima Daiichi	Accepted	Adam Blazowski	FOTA4Climate.org	Poland
44761	12	35	12	35	”Fukishima” should be ”Fukushima”	Accepted	Daniel Westlén	Liberal party Swedish parliament	Sweden
45413	12	35	12	35	"Fukushima" is spelled incorrectly	Accepted	Jessica Lovering	Carnegie Mellon University	United States of America
10081	12	35			Fukushima	Accepted.	Maria E. Mondejar	Technical University of Denmark	Sweden
14451	13	1	13	2	Text suggests that 2 countries represent >50% of total nuclear energy production, but Fig. 6.7 shows that the top-2 countries (i.e. USA and France) represent less than 50% for nuclear.	Accepted. Will be amended to be more accurate and consistent with Figure 6.7 which shows that 2 countries account for almost 50% of energy supply.	Jean-Sébastien Landry	Environment and Climate Change Canada	Canada
1155	13	1			State clearly about "Energy production of all fuels is concentrated."	Accepted. Although clear, this sentence will be slighlty reformulated	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
30933	13	2	13	5	figure 6.6 hydrop/other is signed with a 1 which is not explained	Accepted. Note superscript will be qualified	Pietro Bartocci	University of Perugia	Italy
35381	13	3	13	5	Focussing on the timespan between 1971 and 2016 is flawed since it does not show recent trends and tends to minimize the growth of renewable energies. The IEA Renewable Energy Market Report 2019 forecasts that the world’s total renewable-based power capacity will grow by 50% between 2019 and 2024. https://www.iea.org/reports/renewables-2019#	Accepted. Latest figures if available will be provided	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France
1159	13	3			Represent same or similar figure with different unit (e.g. TWh terawatt.hour) than Millions of tonnes of oil equivalent (Mtoe); or explain what does it mean by 1 Mtoe in the text	Rejected. Comment does not seem to refer to this line. Mtoe already in the metrics and defined	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
31783	13	5	13	8	The two figures are not clear. They do not seem to contain renewables at all in the mix?	Rejected. Renewables are in hydro and others as well as biofuels. However new figure if possible might be considered to show explicitly renewables	Ashok Sreenivas	Prayas (Energy Group)	India

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
202	13	6	13	6	Figure 6.6 and Figure 6.7 are not cited in the text.	Accepted.	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
15137	13	6	13	6	Highly recommend including Russia in the hydropower column as the fifth largest hydropower producer	Rejected. Only the top. Otherwise a different and maybe less relevant table. Russia is cited for natural gas, oil and nuclear	Aleksandr Kraevoy	UC RUSAL	Russian Federation
44763	13	6	13	8	There is a star (*) on coal that is not explained.	Accepted. it will be explained	Daniel Westlén	Liberal party Swedish parliament	Sweden
170	13	6			Figure 6.6 and Figure 6.7 are not cited in the text.	Accepted	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
10891	13	7	13	8	Figure 6.7. It would be useful to have some commentary alongside combustion of the different fossil fuels shown in the figure on the provenance of these fuels. This is especiually pertinent for coal production and the proportion of coal extracted within the USA and China compared with imports, in the latter case including Australian coal exports to China. Trade is also important for understanding characteristics of the energy systems, so should not be neglected form the substantive analysis.	Rejected. Space limitation to address orgin of fuels	Ian Bailey	University of Plymouth	United Kingdom (of Great Britain and Northern Ireland)
18603	13	8	13	8	The figure is insightul but requires a more substantial description. First, there is no source, please add it. Second, we are comparing suppliers of energy carriers (such as Oil - OPEC) with users of energy carriers (such as Nuclear - France). This is highly misleading, as OPEC does not consume the oil it produces, nor France produces the uranium it consumes. Either introduce the figure properly, or revise it to make the supplier/consumer distinction clearer.	Rejected. Figure is only supply not demand. Source is cited above and recited below to be explicit	Thomas Gibon	Luxembourg Institute of Science and Technology (LIST)	France
39807	13	8	13	8	The reference to figure 6.7 should be provided	Accepted. Cited above.	Debadutta Mohanty	CSIR-Central Institute of Mining and Fuel Research	India
19591	13	8			Figure 6.7 which year dose the figure present? 2017?	Accepted. Year will be added in the caption.	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	China
9517	13	9	13	13	explain if and how burning of traditional biofuels is accounted for in the preceding emission numbers and figures.	Rejected. This is beyond the scope of the chapter	Tom Kram	PBL (Fellow)	Netherlands
34199	13	9	14	5	Primary energy sources ?	Rejected. Figure clearly mentions primary energy supply. Nevertheless we shall ensure it is explicit	Antoine BONDUELLE	Climate Action Network France	France
33353	13	9			uses	Rejected.	WERNER MSOKA	UNIVERSITY OF DAR ES SAALAM	United Republic of Tanzania
1157	13	10			Change the words "modern fuel" with more representative words. What does it mean by modern fuel? There can be difference of opinion in the definition of modern fuel if not clearly explained.	Rejected. There is a definition in glossary on modern and traditional biomass. Glossary will be checked to ensure this is covered.	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
36343	13	11			Please be consistent with Fig. 6.2 indicating traditional biomass from bioenergy and not from biofuel	Accepted for fig 6.2. This is consistent with fig 6.7. Biofuels and waste is the concept used by IEA. IPCC lossary provides also definition. Figure 62 will be amended for the primary energy. It will be biomass instead of bioenergy.	Youba Sokona	South Centre	Switzerland
14453	13	12	13	13	Suggest adding text in bracket: "45% of the TPES [for this region] against 9.5% on average worldwide".	Accepted	Jean-Sébastien Landry	Environment and Climate Change Canada	Canada
5879	13	12			The term "biofuels" in the literature usually means liquid and gaseous fuels used for transport. Here the term "biomass" should be used. Also page 14, line 8 and elsewhere. Need to define these terms across the whole report as are often confused.	Accepted. Biofuels will be replaced by biomass. Definitions already in the glossary. No need to repeat definition	Ralph Sims	Massey University	New Zealand
204	13	13	13	13	"…biofuels and waste accounted for 45% of the TPES against 9.5% on average worldwide." This sentence is not clear.	Accepted. It should be added in Africa, mainly sub Saharan Africa	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
12881	13	13	13	13	in Africa to be inserted after TPES	Accepted	ASHOK NEMA	Nuclear Power Corporation of India Limited	India
31785	13	13	13	13	45% TPES from fuelwood is for all of Africa or sub-Saharan Africa?	Accepted.As above. Sentence will be amended	Ashok Sreenivas	Prayas (Energy Group)	India
39809	13	13	13	13	biofuels constitute 45% of TPES for sub-Saharan Africa? Should be mentioned clearly.	Accepted.As above. Sentence will be amended	Debadutta Mohanty	CSIR-Central Institute of Mining and Fuel Research	India
172	13	13			"…biofuels and waste accounted for 45% of the TPES against 9.5% on average worldwide." This sentence is not clear.	Accepted and Amended. See comment excel line 141	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
3077	13				Figure 6.6 does not include year 2018	Accepted. Latest figures will be provided when available.	Ahmed Zobaa	Brunel University London	United Kingdom (of Great Britain and Northern Ireland)
9611	13				Is it possible in Fig. 6.6 to separate hydro from "other" renewables? There is often confusion about how the growth rate in solar & wind energy can be large but the overall contribution of these modes is still small. Showing the data in this figure would be a small way to confront this confusion.	Accepted if information available. Otherwise comment will be added	David Sholl	Georgia Institute of Technology	United States of America

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
206	14	1	14	1	Hydgropower in the scale of GW is not considered as renewable energy or clean energy because of a large scale deforestation and construction of reservoirs. The net CO2 emission is significant over the lifespan of the hydroplant.	Rejected. No agreement that large-scale hydropower is not renewable energy. Environmental impact of hydropower is addressed in 6423. The suggest impact might be added under 6423.	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
208	14	1	14	1	Figure 6.8 is not cited in the text.	Accepted. Will be added at the end o line 9.	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
34151	14	1	14	5	Overlap :Could be removed since there is already a part dealing with hydropower later [suggestion ENSEEIHT INP]	No overlap as objectives and information are different/ Later is on the potential not the capacity and production	Antoine BONDUELLE	Climate Action Network France	France
174	14	1			Hydgropower in the scale of GW is not considered as renewable energy or clean energy because of a large scale deforestation and construction of reservoirs. The net CO2 emission is significant over the lifespan of the hydroplant.	Repeated comment with comment 155	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
19593	14	1			"generated 4,203 TWh in electricity (IEA 2019a)." In the IEA Global Energy & CO2 Status Report 2018, the amount of global hydro power generation is 4239 in 2018.	Rjected, We are taking latest reports available. Not unsual that there are some minor adjustments with previous reports. This is the case between 2018 and 2019 (less than 1%)	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	China
15139	14	2	14	4	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). Highly recommend to enlarge the line 4 and add more countries.	Lines 1 to 5 will be reformulated to capture capacity and production	Aleksandr Kraevoy	UC RUSAL	Russian Federation
13835	14	3	14	3	"China dominates the production […]" should be replaced by "China dominates the installed capacity […]" as GW is a unit of power and not a unit of production. Or production values could be placed instead.	Accepted. Sentence will be reformulated	Alexandre Bizeul	International Energy Agency	France
19595	14	3	14	3	"China dominates the production of hydroelectricity with 695.9 GW, followed by the USA (245.2 GW) and Brazil 4 (135.7 GW)" the figures here is so deffirent from the IEA statistics and China National statistics.	Lines 1 to 5 will be reformulated to capture capacity and production	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	China
37961	14	3	14	3	Production of hydroelectricity is given as numbers of installed capacity (GW) in stead of generation (TWh pr year). The installed capacity is not giving the production. Please change numbers of 695.5 GW for China, 245.2 GW for USA and 135.7 GW for Brazil to actual production/generation of hydroelectricity	Lines 1 to 5 will be reformulated to capture capacity and production	Atle Harby	SINTEF Energy Research	Norway
1629	14	4	14	5	The wording of the sentence is confusing: Trends in new hydroelectric project have remained fairly constant since 2010, except over Asia, where China once again dominates new projects. Does 'trends' just mean that there have been new projects?	Editorial. sentence will be reformulated and more concise.	Jenkins Rhosanna	University of East Anglia	United Kingdom (of Great Britain and Northern Ireland)
9519	14	4	14	5	Unclear, what is "trend….constant"? No increase, or continued at same rate (not specified) as before? Statement on Asia/China is unclear also.	Same as above	Tom Kram	PBL (Fellow)	Netherlands
12367	14	6	14	8	Abbreviation TFC should be written out and explaied the first time it is used	Accepted	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
31787	14	6	14	8	"High demand in Asia after 2000 has been particularly influential. In 2017, Asia accounted for more than a third of TFC.". These sentences together are incogruous considering that Asia has perhaps 50% or more of the world's population. So, if it consumes only a third of TFC, that is hardly surprising. Such paragraphs need to be worded much more carefully.	Noted. This might be considered. But no much space to elaborate further on consumption per capita.	Ashok Sreenivas	Prayas (Energy Group)	India
9521	14	6	14	11	Repair: different units in text (EJ) anf Fig.6.8 (MTOE). Same holds for text/Fig 6.9 and possibly other instances.	Accepted.	Tom Kram	PBL (Fellow)	Netherlands
1161	14	6			Define what is total final energy consumption? Apparently it is electrical energy but there is scope of more precise writing. what is the relevance of the word 'final'?	Rejected. However ensure that TFC acronym is spelled out the first time. TFC is universal concept (all energy). Not only electricity. We shall ensure TFC is in the glossary. Word final is relevant and must stand. It is the final use of the energy.	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
1163	14	8			Define TFC	Same as above	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
30935	14	9	14	12	figure 6.8 Bunkers is not explaine and not cited	Rejected. To be checked if defined in the glossary.	Pietro Bartocci	University of Perugia	Italy
2133	14	11			This figure isn't referred to in the text, but it's very useful. Need to define OECD.	Editorial. Figure number will be explicit. OECD defined for all chapters	Amy Townsend-Small	University of Cincinnati	United States of America
210	14	15	14	15	Figure 6. refers to which figure? There are many such figures in the main texts. The authors have not completed the chapter well. It is so hard to read throught the manuscript.	Accepted. Figure 6.8 instead of figure 6Number may change in SOD	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
12365	14	15	14	15	Please refer to Figure 6.9	Editorial. Accepted.	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
12883	14	15	14	15	figure no. To be corrected to 6.9	Editorial. Accepted. Same as above. All figures will be properly numbered	ASHOK NEMA	Nuclear Power Corporation of India Limited	India
45045	14	15	14	15	Figure 6. needs to be changed to Figure 6.8	Accepted. Same as above.	Ziv Hameiri	The University of New South Wales	Australia

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
6257	14	15	16	28	Page 6-14 line 15 the cited figure is missing, i.e. (Figure 6.). All Figures captured by stating with chapter number followed by the number of Figures. Therefore, the need for proper citation, e.g. Figure 6.8. Page 6-13 line 5 and 8 Figure 6.6 and Figure 6.7 are not cited in the text. And Page 6-16 line 28 also there is an inappropriate caption of Figures in the main text, e.g. (Figure 6.) please work on for the entire chapter.	Accepted. Line 15 is figure 6.8 and not fig 6 Number of figures will be consistent across the whole chapter	Brown Gwambene	Marian University College	United Republic of Tanzania
178	14	15			Figure 6. refers to which figure? There are many such figures in the main texts. The authors have not completed the chapter well. It is so hard to read throught the manuscript.	Repeated comment.	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
2135	14	15			Figure 6.?	Accepted. Editorial. Figure number will be explicit. OECD defined for all chapters	Amy Townsend-Small	University of Cincinnati	United States of America
10083	14	15			Figure 6.9	Accepted. Figure 6.9 and not fig.6	Maria E. Mondejar	Technical University of Denmark	Sweden
17147	14	15			Figure numbers are not correct in some pages of this chapter, for example Figure 6.8 referred to in line 15	Accepted. Figures number will be amended	Deborah Greaves	University of Plymouth	United Kingdom (of Great Britain and Northern Ireland)
19597	14	15			"Fossil fuels still account for an important share of the TFC (Figure 6.)." number of the Figure is missing	ccepted. Figures number will be amended	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	China
35709	14	16	14	16	which reflects better to access to electricity	Editorial. Accepted	Linda Hancock	Centre of Excellence on Electromaterials Science Deakin University	Australia
45047	14	16	14	16	which reflects better to access' need to be changed to 'which reflects better access'	Editorial. Accepted. Same as above.	Ziv Hameiri	The University of New South Wales	Australia
9523	14	16	14	17	Introduction and large-scale sales of new electric appliances warrant explicit mention here.	Noted More details to be addressed under buildings. Limited space.	Tom Kram	PBL (Fellow)	Netherlands
31789	14	17	14	17	It's not clear what "building services" means.	Editorial. Might be reformulated.	Ashok Sreenivas	Prayas (Energy Group)	India
36345	14	17		18	Please be consitent with Fig. 6,.2 indicating traditional biomass from bienergy and not from biofuel	Accepted. There is a definition in glossary on modern and traditional biomass. Glossary will be checked to ensure this is covered.	Youba Sokona	South Centre	Switzerland
31791	14	18	14	18	Fig 6.9 gives this figure in ktoe while the text mentions EJ. Would be good to standardize.	Accepted	Ashok Sreenivas	Prayas (Energy Group)	India
1165	14	18	14	19	Provide reference	Noted. Already in the title. It will be made clearer by repeating at the end of line 19.	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
3079	14				Figure 6.8 does not include year 2018	Accepted. Latest figures will be provided when available.	Ahmed Zobaa	Brunel University London	United Kingdom (of Great Britain and Northern Ireland)
24315	15	1	15	1	Where is the wind in the graph ?	Noted , In the caption wind is clearly shown. However marginal in TFC. Comment might be added	Alan BURLOT	Commissariat à l'énergie atomique et aux énergies alternatives	France
45361	15	1	15	3	Is wind and solar so small it doesn't show or would an alternate color enable tit to be seen in the graph?	Same as above	Deborah Knuckey	Published energy journalist plus consultant for renewable energy development and finance companies through Kiterocket	United States of America
19599	15	1			Figure6.9. the unit may use Mtoe instead of ktoe	Noted and accepted. Scale of units (k or M) will be considered for all figures/	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	China
2137	15	3			Not sure how to interpret this figure. How is heat a final energy source? And wouldn't wind and solar make electricity? If you want to get really technical, natural gas makes heat for cooking and oil makes heat that drives a combustion engine.	Rejected. For instance space heating is a final energy source. Furthermore purpose of this purpose is a methodology to calculate access (borrowed from global tracking framework wich details the methodology)	Amy Townsend-Small	University of Cincinnati	United States of America
212	15	4	15	4	2.7 billions of population don’t have any access to electricity. These people dwell on which countries?	Accepted. We shall add in developing countries particularly sub-Saharan Africa and South Asia.	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
180	15	4			2.7 billions of population don’t have any access to electricity. These people dwell on which countries?	Noted. This is however developed in the box 61 below. To avoid any confusion we may add in developing countries (see box 61)	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
1167	15	4			Provide reference	Noted. Same comment as 23. Reference is provided below. Will make it explicit.	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
1633	15	7	15	7	Should be health not heath.	Editorial. Accepted	Jenkins Rhosanna	University of East Anglia	United Kingdom (of Great Britain and Northern Ireland)
34677	15	7	15	7	in the sentence 'increase heath and climate' should be 'increase health and climate'	Editorial. Accepted	Jordi Solé-Ollé	Spanish National Research Council (CSIC)	Spain
214	15	8	15	8	The title of 6.3.3 is not quite right.	We have replaced the word "continue" with "contribute" in the subsection.	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
33257	15	8	15	12	A major factor which wil affect the energy system is the demography, and development in sub saharan Africa. See for instance WEC 2017 REGIONAL PERSPECTIVEFOR SUB-SAHARAN AFRICA 18 feb 19.	Demography is important, not only for sub saharan Africa, but for the whole continent. See: IEA, Africa Energy Outlook 2019, World Energy Outlook special report, Country report, November 2019 In this report we read (p. 13) "How Africa meets the energy needs of a young, fast growing and increasingly urban population is crucial for the continent's and the world's– economic and energy future. One-in-two people added to the global population between today and 2040 is set to be African, and by 2025, Africa's population exceeds that of both India and China. The continent's urban population is set to grow by more than half a billion over that period, much higher than the growth seen in China's urban population during the country's twodecade economic and energy boom. These profound demographic changes are set to drive economic growth, infrastructure development and, in turn, energy demand".	Marc Darras	Association 4D	France
182	15	8			The title of 6.3.3 is not quite right.	Noted. This will be checked	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia
16257	15	8			In Section 6.3.3 Non-climate factors continue to drive energy systems changes, consider adding a sentence describing how nuclear arms policy influences nuclear power development to new countries in some cases.	Rejected. This is beyond the scope of this chapter.	Daniel Helman	College of Micronesia-FSM	Micronesia, Federated States of
14373	15	9			Viewed globally, climate change (mitigation) is not yet a significant driver of energy system change, this opening sentence should	Noted. editiorial	Michael Bradshaw	University of Warwick	United Kingdom (of Great Britain and Northern Ireland)
14385	15	9			Viewed globally, climate change (mitigation) is not yet a significant driver of energy system change, this opening sentence should be the other way around?	Same as above. editorial change will be considered	Michael Bradshaw	University of Warwick	United Kingdom (of Great Britain and Northern Ireland)
16663	15	9			Climate change is actually a major constraint not a driver. An important point is the well documented correlation between energy consumption and GDP on a planetary scale..	Noted. This point (driver or constraint) will be discussed. As mentioned more details in placeholder	Jean Louis Bobin	Sorbonne universités Paris	France
37853	15	9			This section 6.3.3 should also addreess technological development as a key non-climatic factor of energy systems change	Noted. As mentioned more details in placeholder	Gunnar Luderer	Potsdam Instittute for Climate Impact Research	Germany
29277	15	13	16	25	I see you have a placeholder, but I wanted to emphasise how important it is to explain clearly not only the global challenge on energy access as per SDG7, but also the trade-offs and constraints that it poses for any transformations of energy systems.	Noted. Box can't include all points. However issues raised are addressed in other sections of the report	Vanesa Castan Broto	University of Sheffield	United Kingdom (of Great Britain and Northern Ireland)
31397	15	13	16	25	Here the contradiction between facilitating the access to (clean?) energy and mitigation might be strengthened in the text.	Noted. lines 20-25 are precisely about this contradiction. A couple of lines might be added to strengthen this point as suggested.	Patrick Jochem	German Aerospace Center (DLR)	Germany
41393	15	13	16	25	In this text (Box 6.1) electricity and cooking energy are mixed in every paragraph. This is confusing. Electricity and cooking energy are two distinct energy services which should be kept separate.	Rejected. They are addressed separately although part of the same theme which is access to electricity and modern and clean fuels for cooking.	Cecilia Sundberg	Swedish University of Agricultural Sciences	Sweden
33255	15	19	15	21	See previous remark on SDG's. Better refer to SD in general, Rio, and Rio +20 document § 125-129 of UN document "The future we want" A/Conf.216/L.1 which are the basis for energy and SD, or to the Sustainable Energy for All institution, which has been set in 2011 by Mr. Ban Ki Moon.	Noted. wider framework will be considered	Marc Darras	Association 4D	France
31395	15	20	15	20	Sustainable Development Goals with capital letters	Editorial. Universal rules will be used	Patrick Jochem	German Aerospace Center (DLR)	Germany
12885	15	21	15	23	A definition of modern energy & fuels may be added as the terms are rather vague	Accepted.	ASHOK NEMA	Nuclear Power Corporation of India Limited	India

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
9613	15				Is it possible in Figure 6.9 to separate the contribution of renewable sources of electricity? A common public misconception is that solar/wind are poised to "solve" our energy problems. Showing their overall contribution and discussing in the text what fraction of the total energy is from other places (and especially not used for electricity, which many think of as the only place "energy" goes) would be helpful.	Noted. Section 64 provides information on contribution of renewable electricity (to be checked)	David Sholl	Georgia Institute of Technology	United States of America
39327	16	4	16	6	It is worth while to mention that India has attained 99.93% electrification , with only 18734 households pending to be electrified, although relaibaility can be considered as challenge	India is mentioned. Depending on space we may add some figures regarding achievement in energy access in selected developing countries.	Suvra Majumdar	United Nations Development Programme	India
1169	16	5			Provide reference	Noted. Reference is provided below. Will make it explicit.	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
9525	16	17	16	19	sentence is impossible to follow or understand - please rephrase.	Accepted. Will be reformulated	Tom Kram	PBL (Fellow)	Netherlands
1637	16	24	16	25	Confusing sentence. If possible, reword so 'half of it in Africa' is not at the end. It feels a bit separated from the rest of the sentence by the citation. Possible rewording: This is feasible over the next 20 years, provided that sufficient financial resources are made available for investments (including half of these in Africa) on the order of US$36 billion to US$41 billion/year (Riahi et al. 2012).	Accepted. Suggested reformulation will be considered	Jenkins Rhosanna	University of East Anglia	United Kingdom (of Great Britain and Northern Ireland)
36717	16	26	16	27	This text is not sufficiently based on data. Please, look at data before writing this text. It is misleading. The reality looks for example like Fig. 1 in Blakers et al., "Pathway to 100% Renewable Electricity", IEEE Journal of Photovoltaics 9, 1828 (2019). Annual additions of PV and Wind are **substantially** larger than coal, and this should be told the readers in this context.	Noted. It is a good point that new capacity addition is dominated by renewables, but this section focuses on recent movements in phasing out the existing coal infrastructure and coal use. Strong growth of RE is covered by 6.3.5.	Pietro Altermatt	R&D Center of Trinasolar	Germany
19887	16	26	18	33	Though 6.3.4 addresses "coal phase out", it should also cover "nuclear phase out" as opposite movement and its impact on energy cost, energy security and CO2 emissions should be presented.	Taken into account. While nuclear phaseout provides larger context in certain regions, this section focuses on coal phaseout only. Added one sentence for regional context in the second draft.	Takahiko Tagami	Institute of Energy Economics, Japan	Japan
6345	16	27	16	27	please define more precisely what 'freely-emitting' means	Editorial error corrected in the second draft. Changed to "unabated" coal	Sciacovelli Adriano	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
31399	16	27	16	27	“freely-emitting” is not the right wording here!	Editorial error corrected in the second draft. Changed to "unabated" coal	Patrick Jochem	German Aerospace Center (DLR)	Germany
31793	16	27	16	27	What is "freely emittting coal"?	Editorial error corrected in the second draft. Changed to "unabated" coal	Ashok Sreenivas	Prayas (Energy Group)	India
37381	16	27	16	27	Please be more precise - 'freely emitting' means 'coal generation not equipped with CCS'	Editorial error corrected in the second draft. Changed to "unabated" coal	Michiel Schaeffer	Climate Analytics	Netherlands
45049	16	28	16	28	Figure 6. needs to be changed to Figure 6.9 (I think)	Editorial error corrected in the second draft. Figure 6.6	Ziv Hameiri	The University of New South Wales	Australia
19601	16	28			"began to increase again in 2017 (Figure 6.) " number of the Figure is missing	Editorial error corrected in the second draft. Figure 6.6	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	China
1171	16	34	16	35	Provide reference	Accepeted. Reference (IEA) is provided in the SOD	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
6027	16	35	16	35	To consider including Bangladesh and Pakistan as both countries are actively planting up new coal-fired power plants that are more efficient and with more advanced air pollution control systems	Noted.	SAIK PENG, CASEY NGO	R-SYNC TECHNICAL RESOURCES SDN. BHD.	Malaysia
31401	17	1	17	1	I’m missing the references here.	Accepeted. Reference (IEA) is provided in the SOD	Patrick Jochem	German Aerospace Center (DLR)	Germany
34201	17	3	17	3	"Lower upfront capital investment" relative to which other sources? Coal construction has major investment costs and a long timeframe for building generally, maybe this part could be precised. This part on the role of coal power and gas is key, but maybe it could be coordinated with Chapter 15 on Investment and Finance.	Accepted. Replaced "lower upfront capital investment" with "lower costs traditionally perceived" in the second draft.	Antoine BONDUELLE	Climate Action Network France	France
24317	17	4	17	4	The words « some distance » is vague.	Editorial, corrected.	Alan BURLOT	Commissariat à l'énergie atomique et aux énergies alternatives	France
1173	17	4			Be more precise in the statement "Major coal using countries are still some distance from phasing it out (Spencer et al. 2018)."	Editorial, corrected.	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
36715	17	6	17	7	"Cheap coal is the choice of fuel in ... China" While an impressive 130 GW of coal capacity is currently under construction in China, and 30 GW of coal capacity was added in 2018, China has also ambituous activites in renewables. The fact that 'only' 30.1 GW of PV was installed in 2019 compared to 44 GW PV in 2018 is because renewables are now installed subsidy-free. China added 20 GW of wind energy in 2018 and 26 GW in 2019. My main point here: renewable additions are too big to be ignored. Please do not ignore them but acknowledge them as a path that is working out. For a global quantification of new power generation additions, please see https://bioenergyinternational.com/heat-power/renewable-energy-accounts-for-a-third-of-global-power-capacity (for example the first figure is compelling)	Strong growth in RE is covered by 6.3.5, while this section focuses on recent movements in phasing out coal.	Pietro Altermatt	R&D Center of Trinasolar	Germany
2141	17	6			Replace GHG with CO2	Rejected. Unclear which text this comment refers to	Amy Townsend-Small	University of Cincinnati	United States of America
1639	17	9	17	10	Should this be a 'just transition for the workforce' rather than to the workforce? Recommend briefly explaining what you mean by 'just' because it seems a little out of context.	Taken into account. The just transition challenge is discussed in Box 2 and 6.7	Jenkins Rhosanna	University of East Anglia	United Kingdom (of Great Britain and Northern Ireland)
31795	17	9	17	10	While renewables may have greater employment potential, a just transition would require the same workforce currently employed in the fossil fuel sectors to be accommodated in renewables (or elsewhere) - which is a very different question. It would be good to mention this.	Accepted. Texts on job impact are revised, and the just transition challenge is discussed in Box 2 and 6.7	Ashok Sreenivas	Prayas (Energy Group)	India
24319	17	10	17	10	The number of jobs, even if based on a publication, seems a bit vague as a worldwide estimation on the entierety of renewable jobs.	Accepted. Texts on job impact are revised, and the just transition challenge is discussed in Box 2 and 6.7	Alan BURLOT	Commissariat à l'énergie atomique et aux énergies alternatives	France
31673	17	10	17	10	The number of jobs, even if based on a publication, seems a bit vague as a worldwide estimation on the entirety of renewable jobs.	Repeated comment	Alan BURLOT	Commissariat à l'énergie atomique et aux énergies alternatives	France
39713	17	10	17	18	These paragraphs ignore that macro- and micro-algae offer potential - the first in the context of sustainable coastal zone management and as an alternative to fishing, the latter a land-based resource with relatively low land foodprint. Furthermore, the reference for the potentials is outdated. For a more reasonable range of sustainable biomass potentials see e.g. Beuchelt, Tina & Nassl, Michael (2019) Applying a Sustainable Development Lens to Global Biomass Potentials. Sustainability 11 (18): 5078; IRENA (2019) Sustainable harvest: Bioenergy potential from agroforestry and nitrogen-fixing wood crops in Africa. International Renewable Energy Agency. Abu Dhabi https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Jan/IRENA_Sustainable_harvest_2019.pdf; Wu, Wenchao et al. (2019) Global advanced bioenergy potential under environmental protection policies and societal transformation measures. GCB Bioenergy 11 (9): 1041-1055; Faaij, André (2018) Securing sustainable resource availability of biomass for energy applications in Europe; review of recent literature. University of Groningen https://bioenergyeurope.org/wp-content/uploads/2018/11/Bioenergy-Europe-EU-Biomass-Resources-Andr%C3%A9-Faaij-Final.pdf; IEA (2017) Technology Roadmap: Delivering Sustainable Bioenergy. International Energy Agency and IEA Bioenergy TCP. Paris http://www.iea.org/publications/freepublications/publication/Technology_Roadmap_Delivering_Sustainable_Bioenergy.pdf; Kluts, Ingeborg et al. (2017) Sustainability constraints in determining European bioenergy potential: A review of existing studies and steps forward. Renewable and Sustainable Energy Reviews 69: 719-734; Nogueira, Luiz et al. (2017) Sustainable and Integrated Bioenergy Assessment for Latin America, Caribbean and Africa (SIByl-LACAf): The path from feasibility to acceptability. Renewable and Sustainable Energy Reviews 76: 292-308; USDOE (2017) 2016 Billion-Ton Report - Advancing Domestic Resources for a Thriving Bioeconomy Vol 2: Environmental Sustainability Effects of Select Scenarios from Vol 1. US Department of Energy. Washington, DC https://energy.gov/eere/bioenergy/downloads/2016-billion-ton-report-volume-2-environmental-sustainability-effects; Skeer, Jeffrey & Nakada, Shunichi (2016) Potential for Biomass and Biofuel through Sustainable Intensification of Agriculture and Reduction of Food Losses and Waste. Natural Resources 7: 23-27; WBA (2016) Global biomass potential towards 2035. WBA Fact Sheet.	Taken into account. This section contains the current trends in energy systems but biomass potential is included in section 6.4.2.6. There, we have provided detailed potential estimates for different biomass sources. Projections about bioenergy deployment has also been provided there.	Uwe Fritsche	IINAS	Germany

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
39713	17	10	17	18	Comment continued: World Biomass Association. Stockholm; Deng, Yvonne et al. (2015) Country-level assessment of long-term global bioenergy potential. Biomass and Bioenergy 74: 253-267; Mauser, Wolfram et al. (2015) Global biomass production potentials exceed future demand without the need for cropland expansion. Nature Communications 6: 8946; Klein, David et al. (2014) The global economic long-term potential of modern biomass in a climate-constrained world. Environ. Res. Lett. 9: 074017; Searle, Stephanie & Malins, Chris (2014) A reassessment of global bioenergy potential in 2050. GCB Bioenergy doi: 10.1111/gcbb.12141; Slade, Ralph; Bauen, Ausilio & Gross, Robert (2014) Global bioenergy resources. Nature Climate Change 4: 99-105; EEA (2013) EU bioenergy potential from a resource efficiency perspective. EEA Report No 6/2013. Copenhagen http://www.eea.europa.eu/publications/eu-bioenergy-potential/at_download/file; Elbersen, Berien et al. (2013) Assessing the effect of stricter sustainability criteria on EU biomass crop potential. Biofuels, Bioproducts and Biorefining 7 (1): 173-192; Haberl, Helmut et al. (2013) Bioenergy: how much can we expect for 2050? Environ. Res. Lett. 8: 031004; Schueler, Vivien et al. (2013) Global biomass potentials under sustainability restrictions defined by the European Renewable Energy Directive 2009/28/EC. GCB Bioenergy 5 (6): 652-663; Erb, Karl-Heinz; Haberl, Helmut & Plutzar, Christoph (2012) Dependency of global primary bioenergy crop potentials in 2050 on food systems, yields, biodiversity conservation and political stability. Energy Policy 47 (4): 260-269; Rogner, H-H. et al. (2012) Chapter 7 - Energy Resources and Potentials. In: Johansson, Thomas et al. (eds). Global Energy Assessment - Toward a Sustainable Future. Cambridge, UK; New York, NY; Laxenburg: 423-512;		Uwe Fritsche	IINAS	Germany
1175	17	11			What is M?	Noted. Texts on job impact are revised.	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
19603	17	11			"2.65 jobs per $1M" what does the $1M mean? Sale , profit or investment?	Noted. Texts on job impact are revised.	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	China
37383	17	15	17	17	It is unclear why this argument on fugitive emission concerns for natural gas is presented in the coal section. There are concerns beyond this for gas infrastructure, including the actual emissions from power generation as well, and this single sentence, out of context, is misleading.	Accepted. This paragraph is rewritten in the second draft	Michiel Schaeffer	Climate Analytics	Netherlands
37387	17	17	17	20	should refer to PA consitent pathways, not 2dC pathway, and IPCC SR 15 has outlined more precisely the need to phase out coal to achieve PA LTTG, see also Parra et al 2020	Taken into account. Texts are revised in SOD	Michiel Schaeffer	Climate Analytics	Netherlands
2139	17	17			I think this mention of methane leakage should be expanded here. Also, what "literature" are you referring to - prior IPCC reports?	Rejected, methane leakage from unconventional gas production is not directly on coal phaseout. Texts are revised in SOD.	Amy Townsend-Small	University of Cincinnati	United States of America
31403	17	18	17	19	Why not 1.5°C? What do you mean by margins?	Taken into account. Texts are revised in SOD	Patrick Jochem	German Aerospace Center (DLR)	Germany
26313	17	21	17	21	Japan may deserve a mention somewhere in this box to illluminate that coal phaseout is not uniformly happening (or plannned) even in developed countries. The latest Strategic Energy Plan of Japan describes that 26% of energy mix comes from coal in 2030. The Long-term Strategy under the Paris Agreement, the latest Japanese decarbonization plan by 2050, does not include the coal phaseout. Also, the country offers a unique case, regarding the fact that it is exporting coal plants to developing countries, an indisutrial initiative lead by the government and related ministries (Aldrich et al., 2019, 10.1038/s41558-019-0510-0).	Taken into account. Japan and South Korea are mentioned in the main text, but not called out in the box due to word limit.	Tanaka Katsumasa	Laboratoire des Sciences du Climat et de l'Environnement (LSCE), CEA, FRANCE; National Institute for Environmental Studies (NIES), JAPAN	France
11527	17	21	18	33	The decicion of the EIB to stop funding of fossil energy projects from 2021 on is missing. A discussion about the econmic pressure on coal fired power stations is missing.	Noted. This is mentioned in Box already.	Arnulf JÄGER-WALDAU	European Commission, JRC	Italy
5881	17	21			Also need a similar box on future oil/gas exploration and current government bans - eg New Zealand	Rejected due to space limit	Ralph Sims	Massey University	New Zealand
17363	17	22	17	24	According to discussions held during COP25 and lack of international consensus in IPCC special report on the impacts of global warming of 1.5 °C above pre-industrial levels, the mentioned texts should appear to be reviewed.	Noted	Zeyaeyan Sadegh	Islamic Republic of Iran Meteorological Organization (IRIMO)	Iran
29085	17	22	18	35	Box 6.2 and 17.1 (Ch 17) focus on coal phase out and just transition. Please check for overlap	Noted. Box 6.2 is revised and restructured to highlight coal phaseout as a cross-cutting issue.	Minal Pathak	Ahmedabad University	India
17699	17	24	17	25	Actually the coal reduction in UK has been even faster than this and has followed surprisingly well the implications of a logistic substitution process - as estimated (rather crudely) in Grubb (2018), 'Conditional optimism: Economic Perspectives on Deep Decarbonization', INET, 5 Dec 2018. https://www.ineteconomics.org/perspectives/blog/growth-with-decarbonization-is-not-an-oxymoron	Noted. Clarify this is global average	Michael Grubb	UCL - Institute of Sustainable Resources	United Kingdom (of Great Britain and Northern Ireland)
8865	17	31	17	31	It would be interresting to explicit which countries are member of PPCA. This would help to understand the whole paragraph.	Taken into account. Mention a few country member examples but not all members due to space limit.	Michel SIMON	Vice Président SFENRAL	France
37389	17	31	17	48	Descrption of PPCA members not up to date. Germany member but not with a coal phase out target in line with PPCA statement (oecd phase out by 2030).	Noted.	Michiel Schaeffer	Climate Analytics	Netherlands

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5707	17	32	17	32	committed *to*	Editorial, corrected.	paul fennell	Imperial College	United Kingdom (of Great Britain and Northern Ireland)
1177	17	32			Provide reference. One basic tenet of scientific writing is the correct citation of previous works which strengthens the credibility of the underlying study.	Accepted. Reference is added in the SOD	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
5709	17	34	17	34	premature, not pre-mature	Editorial, corrected.	paul fennell	Imperial College	United Kingdom (of Great Britain and Northern Ireland)
4875	17	35	17	37	Worth noting that Germany is slated to phase out coal based electricity production by 2038 (Source: https://www.bmwi.de/Redaktion/DE/Downloads/A/abschlussbericht-kommission-wachstum-strukturwandel-und-beschaeftigung.pdf?__blob=publicationFile&v=4)	Noted.	Patrick Lamers	National Renewable Energy Laboratory	United States of America
9993	17	37	17	37	"A major issue for phasing-out coal here is institutional lock-in". For Poland, this is a good reference: - Antosiewicz, M., Nikas, A., Szpor, A., Witajewski-Baltvilks, J., & Doukas, H. (2019). Pathways for the transition of the Polish power sector and associated risks. Environmental Innovation and Societal Transitions.	Noted.	Haris Doukas	School of Electrical and Computer Engineering, National Technical University of Athens	Greece
6453	17	37	17	38	missing: "by using", or similar	Editorial, corrected.	Paul Neetzow	Humboldt-Universität zu Berlin	Germany
34153	17	37	17	38	Sentence isn’t clear [suggestion ENSEEIHT INP]	Editorial, corrected.	Antoine BONDUELLE	Climate Action Network France	France
1179	17	37			State more on what does it mean by "institutional lock-in'	Taken into account. Rephrased in the SOD.	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
18673	17	38	17	38	complete phase-out may be possible only financial instruments' - seems like something is missing here	Editorial, corrected.	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
45051	17	38	17	38	be possible financial' needs to be changed to ' possible only by finanacial'	Editorial, corrected.	Ziv Hameiri	The University of New South Wales	Australia
44379	17	38			typo: "complete phase-out may be possible only financial instruments" should be "a complete phase-out may be possible only through [or "with"] financial instruments"	Editorial, corrected.	Pietro Guarato	University of Lausanne	Switzerland
31797	17	41	17	41	Isn't the German deadline of 2038 to phase out coal for all usage, not just electricity generation?	It is coal power generation	Ashok Sreenivas	Prayas (Energy Group)	India
24669	17	41	17	43	the German Coal Commission recommandatiosn were adopted by German government by the end of 2019. The coal phase out is officially planned for 2038, with a possibilty to be anticipated until 2035 according to econmic circumstances	Taken into account in SOD	Florent LE STRAT	ELECTRICTE DE FRANCE	France
1181	17	41			Also mention the earliest year, if possible, and put reference	Noted.	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
14455	17	46	17	47	I don't understand the rationale for why "high historical emissions" from coal implies that "coal phase-out alone will not lead to adequate decarbonization".	Taken into account. Sentence is dropped, not directly relevant to coal phaseout.	Jean-Sébastien Landry	Environment and Climate Change Canada	Canada
8867	17	46	17	48	Coal phase out must be supplemented bu renewable, nuclear and NETs. It is obvious that renewable alone will not be adequate to serve a robust and resilent european electrical network.	Taken into account. Sentence is dropped, not directly relevant to coal phaseout.	Michel SIMON	Vice Président SFENRAL	France
37385	17	46	17	48	Neither of the two sources cited, Heinrichs et al 2017 or Figuiredo et al. 2019 make the argument that NET adoption is necessary is - they argue that further decarbonisation of other sectors is required, but Figuiredo et al argue for higher renewable penetration. The additional conclusion on NET adoption needs to either be removed, or bolstered with further justification from the literature.	Taken into account. Sentence is dropped, not directly relevant to coal phaseout.	Michiel Schaeffer	Climate Analytics	Netherlands
1183	17	47			Write the full form of NETs	Editorial, corrected.	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
1643	17		17		The information on this page feels very repetitive. I think the text in the first couple of paragraphs could be shortened as the Box is so detailed.	Taken into account. Section 6.3.4 and Box 6.2 are revised and restrucured in the second draft	Jenkins Rhosanna	University of East Anglia	United Kingdom (of Great Britain and Northern Ireland)
14457	18	1	18	3	The Dolter and Rivers (2018) study did not look at the impact of "cheap shale gas" on "coal use" in Canada. There seems to be a miscitation here.	Accepted. Reference is updated in the SOD	Jean-Sébastien Landry	Environment and Climate Change Canada	Canada
1185	18	4			Write the full form of CCS	Editorial, corrected	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
18605	18	5	18	6	I welcome the mention of environmental co-benefits of a coal phase-out, this is a very important topic in energy policy. These co-benefits have been quantified prospectively, not only for North America, but also for every region of the world. I would recommend citing Hertwich et al. (2015) (doi.org/10.1073/pnas.1312753111) or more recently Luderer et al. (2019) (https://doi.org/10.1038/s41467-019-13067-8).	Taken in to account. Non-climate drivers of coal phaseout is discussed in the main texts.	Thomas Gibon	Luxembourg Institute of Science and Technology (LIST)	France
6057	18	11	18	11	Abbreviations used i.e. BECCS is not defined in full in the text for the first time of use. Also there is no list of abbreviations for reference for other abbreviations used in the entire chapter 6.	Editorial, corrected.	SAIK PENG, CASEY NGO	R-SYNC TECHNICAL RESOURCES SDN. BHD.	Malaysia

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1187	18	11			Write the full form of BECCS	Editorial, corrected	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
24629	18	12	18	12	Solar and wind power generation growth in Iran is much lower than the world average	Unclear which texts this comment refers to	Sanaz Jafarzadeh	Thermal Power Plants Holding Company	Iran
2143	18	12			has CSP already been defined?	Accepted. Full form added	Amy Townsend-Small	University of Cincinnati	United States of America
1189	18	12			Provide reference or align the statement with the available references	Rejected. No reference needed here	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
37391	18	22	18	22	The citation should read 'Global Energy Monitor 2019'	Editorial, corrected.	Michiel Schaeffer	Climate Analytics	Netherlands
10893	18	23	18	23	Is it worth adding a separate element to this text box summarisng the current and project situation in Australia as an OECD country that still relies on coal for a significant proportion of its energy needs and which is still a major coal exporter, especially to the Asian market. This, of course, includes substantial new coal infrastructure devlopment, most notably the Adani Carmichael development that will create substantial coal lock-in for several decades unless China and India develop clear coal phase-out plans.	Noted. Agreed supply side is also important, mentioned in the main text. All the cases here mainly focus on coal use phaseout	Ian Bailey	University of Plymouth	United Kingdom (of Great Britain and Northern Ireland)
8871	18	23	18	33	In Africa, it shoud be noted tgat the developmment of large dams (Nile and Congo rivers) will have a great impact on level of electricity supply, health effects, social and economic benefits.	Noted. But not directly on coal phaseout	Michel SIMON	Vice Président SFENRAL	France
1191	18	26			Replace 'mid-century' with 'around 2050'	Editorial, corrected	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
37943	18	27	18	29	The need for equitable redeployment of energy workers to the renewable sector while meeting everyone's energy needs renewably and equitably is urgent throughout Africa and in all non-Annex I countries; this is particularly pressing in South Africa because of the large number of coal miners, not just due to income inequality.	Taken in to account.	Patricia Perkins	York University	Canada
17701	18	34	18	48	Sorry to sound like a stuck record and I don't really know how to answer my own questino about this. It is not surprising there are bumps in the road when supports are slashed on the grounds that a technology is now competitive. This section is really interesting and has the essence of mapping out something that needs not linear but dynamic extrapolation to test the statement - actually a hypothesis or asdsumption - of the section title	Taken into account. The point we are trying to make here is that solar and wind capacity has increased in this decade but their share in the electricity generation is still 2% and 4%, respectively. The title and text has been modified for further clarity.	Michael Grubb	UCL - Institute of Sustainable Resources	United Kingdom (of Great Britain and Northern Ireland)
44765	18	34	20	11	The discussion on growth of wind and solar PV is given exclusively as installed power in MW. It would be good to also include data on given amount of electricity in GWh or other relevant unit.	Accepted. Share of solar PV and wind in generation mix was added in SOD	Daniel Westlén	Liberal party Swedish parliament	Sweden
31405	18	35	18	48	I'm missing references!	Accepted. References added to the SOD	Patrick Jochem	German Aerospace Center (DLR)	Germany
1193	18	35			Mention the definition of levelized cost of electricity (LCOE)	Taken into account. Definition shall be included in Annex to the report (as in case of AR5)	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
8869	18	36	18	36	Add the word "capacity". : Power generation capacity, TWe… to distinguish from production (TWh)	Taken into account. Capacity and production specified where necessary in the SOD	Michel SIMON	Vice Président SFENRAL	France
14459	18	36	18	36	It should be "Generation capacity" instead of "Power generation"; 480 TW is a measure of capacity, not generation.	Taken into account. Capacity and production specified where necessary in the SOD	Jean-Sébastien Landry	Environment and Climate Change Canada	Canada
20609	18	36	18	37	On page 18 line 37 it is stated that "power generation" increased to 480 TW. Note that the 'Watt' is a unit of power, not power generation, which is Watt-Hours of Joule.	Taken into account. Capacity and production specified where necessary in the SOD	Vassilis Daioglou	Copernicus Institute of Sustainable Development	Netherlands
20611	18	36	19	11	While on page 18 line 37 it is stated that power generation increased to 480 TW (see previous comment for unit mistake), in table 6.2 the totlal world cumulatively installed power is 480610 MW. If I understand correctly, these numbers should be the smae but they are off by a factor of 1000. Please check the units.	Taken into account. Unit was corrected. The 480 TW number was dropped while rewriting the text in SOD	Vassilis Daioglou	Copernicus Institute of Sustainable Development	Netherlands
13837	18	37	18	37	Error of unit : installed capacity is 480 GW and not 480 TW. Cf table 6.2 in the next page with correct value.	Editorial. Units rectified. The 480 TW number was dropped while rewriting the text in SOD	Alexandre Bizeul	International Energy Agency	France
18675	18	37	18	37	438 TW should be 438 GW	Editorial. Units rectified. The 480 TW number was dropped while rewriting the text in SOD	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
1195	18	37			Provide reference	Taken into account. Some text was rewritten and citations included now in SOD	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
19605	18	37			"over 480 TW" unit should be TWh	Editorial. Units rectified. The 480 TW number was dropped while rewriting the text in SOD	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	China
1197	18	39			Provide reference	Taken into account. Some text was rewritten and citations included now in SOD	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
1521	18	40	18	40	Suggested additional literature on the state of PV in EU countries, from the EU Eurobserver project: https://www.eurobserv-er.org/pdf/18th-annual-overview-barometer/ (page 14, overview) https://www.eurobserv-er.org/photovoltaic-barometer-2019/ (detailed report)	Taken into account. Literature from the report cited in the context of European solar capacity	Paul Vethman	PBL Netherlands Environmental Assessment Agency	Netherlands

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
11529	18	40	18	42	European installations declined after 2011, but started to rebound in 2018 (https://doi.org/10.3390/en13040930)	Taken into account. Suggested literature cited in the context of European solar capacity	Arnulf JÄGER-WALDAU	European Commission, JRC	Italy
1201	18	40	18	48	Provide related figures; a lot of numbers in a paragraph sometimes confound the reader	Taken into account. Table 6.2 and figure 6.10 summarize the key numbers in the text	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
6347	18	40	18	48	Please also report the total installed capacity of solar generation, possibly with an additional chart	Taken into account. The share of solar generation and its rise between 2014 and 2018 in total electricity generation is now included in the first paragraph of 6.3.5	Sciacovelli Adriano	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
1523	18	41	18	41	The 22 GW figure should be 23 GW, according to Eurobserver data?	Accepted. Necessary changes made with suitable citations	Paul Vethman	PBL Netherlands Environmental Assessment Agency	Netherlands
1199	18	42			Review the sentence "In 2018, the share of total global cumulative capacity of Europe decreased to 25%."; provide reference	Taken into account. Some text was rewritten and citations included now in SOD	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
35711	18	45	18	48	sometimes in this chapter statistics are cited without the source.	Taken into account. Citations added whereever necessary	Linda Hancock	Centre of Excellence on Electromaterials Science Deakin University	Australia
18677	18	47	18	47	The % values with countries are not listed in order from largest to smallest	Noted. The text was removed in SOD but the % values are available in the Table 6.2	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
19607	18	47			"the largest cumulative installed capacity globally are China (34%)" the share of China is 36.4% in Table6.2	Noted. Text dropped. Table 6.2 shows the figure now (updated to 2019)	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	China
16665	18		21		Why is solar thermal overlooked?	Taken into account. Concentrated Solar Thermal Power (CSP) is discussed in brief as recent trends do not suggest much progress in this technology as compared to PV. But more detailed dicussion is covered in 6.4.2.1 Solar Energy	Jean Louis Bobin	Sorbonne universités Paris	France
24617	18				Solar and wind power generation growth in Iran is much lower than the world average	Noted.	Sanaz Jafarzadeh	Thermal Power Plants Holding Company	Iran
5711	19	1	19	2	The statement "thus, most rapid growth has been seen in the US and EU" is at odds with table 6.2, where the majority of PV is in China, with the highest growth rate being in Eurasia, middle east and India. The whole paragraph needs definition of growth rate (absolute? As a % of installed capacity? and careful checking with table 6.2.	Taken into account. Text revised to make in consistent with table 6.2	paul fennell	Imperial College	United Kingdom (of Great Britain and Northern Ireland)
6161	19	1	19	2	As has been shown in several papers (mentioned later in section 6.3.8), the major driver for PV deployment is policy (basically, economic support), not differences in solar resources.	Taken into account. The text was dropped but the drivers for PV deployment are discussed in detail in section 6.4 along with policy support in 6.3.8	Linares Pedro	Universidad Pontificia Comillas	Spain
9025	19	1	19	2	I doubt that the rapid growth in PV installations in Europe can be attributed to favourable solar resources. Average surface solar downwelling radiation in Germany, for instance, is a lot lower than in many other places. Nevertheless installed PV capacity is quite high there. I would rather draw the opposite conclusion: apparently ideal capacity factors are less important than targeted policies. Compare also with p. 31 ll. 21F which reports higher costs in California as compared to Germany even though solar resource would suggest the opposite.	Taken into account. The text was dropped but the drivers for PV deployment are discussed in detail in section 6.4 along with policy support in 6.3.9	Jan Wohland	ETH Zürich	Switzerland
36719	19	1	19	2	Currently, the substantial regional differences come from policy and institutions rather than irradiation. I assume, you mean after the energy transition. Therefore, I suggest to add "After the energy transition, " in front of this sentence.	Taken into account. The text was dropped but the drivers for PV deployment are discussed in detail in section 6.4 along with policy support in 6.3.10	Pietro Altermatt	R&D Center of Trinasolar	Germany
18679	19	2	19	2	Throughout the chapter, US or U.S. or USA and E.U. or EU etc. For consistency, whatever acronym is chosen should be kept throughout.	Editorial. Taken into account in SOD	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
36721	19	2	19	3	"Thus, most rapid growth has been seen in the U.S. and E.U." To what variable do you relate "most rapid"? Most new PV power additions occur in China, by far; per capita in Australia by far, see Fig. 5 in Blakers et al., "Pathway to 100% Renewable Electricity", IEEE Journal of Photovoltaics 9, 1828 (2019), followed by Germany, China and Japan; in % of growth, according to your table 6.2 in "Asia Pacific". Your reference (Breyer et al 2017) has been substtantially updated due to falling prices. i suggest to replace it with their report available at: http://energywatchgroup.org/new-study-global-energy-system-based-100-renewable-energy . If you prefer a reviewed journal paper: Eero Vartiainen et al, "Impact of weighted average cost of capital, capital expenditure, and other parameters on future utility-scale PV levelised cost of electricity", Progress in Photovoltaics, in print, appeared online in 2019: https://doi.org/10.1002/pip.3189	Taken into account. Text was rewritten to update the numbers and reflect the latest trends	Pietro Altermatt	R&D Center of Trinasolar	Germany
1203	19	4			Include what is NDC	Accepted	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
41983	19	6	19	8	"give rise to improved performance of health and water desalination (<INCLUDE CITATION HERE>), indicating crucial linkages to food conservation (therefore, food security), thus adaptation and sustainable development goals"	Accepted.	Francisco Javier Hurtado Albir	European Patent Office	Germany
35713	19	7	19	7	editing - indication crucial linkages- should be indicating crucial linkages	Editorial. Corrected in SOD	Linda Hancock	Centre of Excellence on Electromaterials Science Deakin University	Australia
28857	19	9	19	11	Give the separator for cummulative installed.	Noted	Marissa Malahayati	National Institute for Environmental Studies	Japan
39329	19	10	19	10	The cumulative installation of solar PV including solar rooftop is now (Feb 2020) is 34405 MW , moreover the capacity of renewable based power generation has increased by 24.47% in compared to coal based power generation growing by mere 3.39% during 2018-19 signifying the shift in thrust in renewable	Taken into account. The table 6.2 was updated with 2019 numbers. Share of solar PV and wind in the generation mix in 2014 and 2018 included in the text now.	Suvra Majumdar	United Nations Development Programme	India
10895	19	10	19	11	Looking at Table 6.2, the point could be stressed, without becoming policy prescriptive, that substantial capacity exists for further development of PV in many regions of the world, particularly North America, Asia, Africa and South America to achieve generation levels that are more comparable with those in Germany and Europe more generally. Comparative statemens could also accompany Figure 6.10.	Rejected. The potential and drivers for growth are discussed in detail in section 6.4. Here the analysis is restricted to recent trends	Ian Bailey	University of Plymouth	United Kingdom (of Great Britain and Northern Ireland)
37975	19	10	19	11	I suggest to add a column in Table 6.2 with power generation. The installed capacity tells little about the actual energy generated	Taken into account. The share of solar generation and its rise between 2014 and 2018 in total electricity generation is now included in the first paragraph of 6.3.5	Atle Harby	SINTEF Energy Research	Norway
1205	19	10			Include what is this share in the 4th column of the table?	Figure modified. New figure reflects the share of installed capacity in 2019	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
11531	19	10			The MW given in this table mix AC and DC and are therfore missleading. E.g. India is AC capacity, Germany DC capacity	Noted. The capacity for all regions and countries are quoted from the same source (IRENA 2020 Statistics) and are comparable	Arnulf JÄGER-WALDAU	European Commission, JRC	Italy
36723	19	12	19	13	I sugggest "Concentrating solar power (CSP)" instead of just using "CSP" because the acronym has not been used in Chapter 6 so far.	Accepted	Pietro Altermatt	R&D Center of Trinasolar	Germany
1525	19	12	19	15	CSP shows a growing trend again in the EU. See Eurobserver, https://www.eurobserv-er.org/solar-thermal-and-concentrated-solar-power-barometer-2019/.	Noted. The text does not mention the specific trend in Europe. It just says that the CSP capacity in Europe is concentrated in Spain. Further discussion on CSP technology is convered in section 6.4	Paul Vethman	PBL Netherlands Environmental Assessment Agency	Netherlands
8817	19	12	19	15	It would be important to highlight the planned / under construction capacity which is mostly in the MENA region, so the installed CSP capacity will diversify from the US and EU to other parts of the world.	Rejected. This section focuses on recent trends and future projections are covered in later parts of the chapter	Saygın Değer	SHURA Energy Transition Center	Turkey
34679	19	12	19	15	While both Spain and USA do not expect to further grow with new projects, China, Morocco and South Africa will lead the new projects of deployment. CSP it is forecast to grow to 3.4 GW in the period 2019-2024: IEA (2019), "Tracking Power", IEA, Paris https://www.iea.org/reports/tracking-power-2019	Rejected. This section focuses on recent trends and future projections are covered in later parts of the chapter	Jordi Solé-Ollé	Spanish National Research Council (CSIC)	Spain
34203	19	12	19	21	A comparison with PV volumes and cost would be useful	Taken into account. The discussion on PV costs is now shifted to section 6.4	Antoine BONDUELLE	Climate Action Network France	France
1207	19	12			Include what is CSP	Accepted	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
31799	19	14	19	14	What is DNI?	Full form included	Ashok Sreenivas	Prayas (Energy Group)	India
1645	19	14	19	15	Include the word 'globally' at the beginning of the sentence. The previous sentence only considers Europe.	Accepted	Jenkins Rhosanna	University of East Anglia	United Kingdom (of Great Britain and Northern Ireland)
1209	19	14			Include what is DNT	It is DNI. Full form provided	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
16521	19	14			What is the meaning of DNI?	Direct Normal Irradiance (DNI)	Lining WANG	Economics and Technology Research Institute, CNPC	China
1527	19	16	19	16	This section on wind power may add something about expected installations, for example in Europe. There are enormous plans for wind offshore towards 2050 in the EU green deal policy agreement. So far they are only ambitions, which could be mentioned though to reflect on the carbon reduction strategy for EU countries. News item: https://windeurope.org/about-wind/reports/our-energy-our-future/	Rejected. This section focuses on recent trends and future projections are covered in later parts of the chapter	Paul Vethman	PBL Netherlands Environmental Assessment Agency	Netherlands
1211	19	16	19	17	Rewrite the sentence in a better way	Accepted. Sentence rewritten for better clarity	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
36725	19	16	19	17	I am not an expert in wind energy, but I miss here a description of the dynamics of wind power additions: these are falling (in terms of GW/yr) since 2015. Your text buries this fact, so does Fig. 6.10. It is much more direct to display yearly additions instead of cumulative installed capacities to reveal the trends. This is common scientific practice and I strongly recommend to follow this practice.	Taken into account. Figure 6.10 is now modified to reflect yearly addition of solar and wind capacity and the cumulative growth is covered in the text and Tables 6.2a and 6.2b	Pietro Altermatt	R&D Center of Trinasolar	Germany
37977	19	16	20	8	Please also give numbers of wind power generation, not only installed capacity	Figure changed. Suggestion taken into account in new figure and elsewhere in the text	Atle Harby	SINTEF Energy Research	Norway
13839	19	17	19	17	Better write "10 GW" instead of "10 000 MW" to harmonise units used in this chapter.	Taken into account. This particular number was dropped but GW was used in other places	Alexandre Bizeul	International Energy Agency	France
45363	19	17	19	17	Change measurement term to GW to match preceeding and following measures "more than 10 GW"	Taken into account. This particular number was dropped but GW was used in other places	Deborah Knuckey	Published energy journalist plus consultant for renewable energy development and finance companies through Kiterocket	United States of America
28859	19	21	19	21	Give the units on y-axis	Figure changed. Noew figure has the unit on y-axis	Marissa Malahayati	National Institute for Environmental Studies	Japan
31407	19	21	19	21	Please delete the title in the figure (there is still a title below).	Figure changed. Title removed in new figure	Patrick Jochem	German Aerospace Center (DLR)	Germany
2337	19	22	19	22	Eliminate in figure numbers after decimal separator	Figure changed. Suggestion taken into account	Dieter Boer	Universitat Rovira i Virgili	Spain
1213	20	3	20	8	Provide related figures; a lot of numbers in a paragraph sometimes confound the reader	Taken into account. More detailed tables for wind and solar capacity were included in SOD	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
2145	20	9	20	11	This is so exciting and cool!!!	Noted.	Amy Townsend-Small	University of Cincinnati	United States of America
9027	20	9	20	11	I wonder if it makes senses to include plans for floating offshore here. A recent IEA report suggest large potentials and there are some projects currently in the pipeline. References IEA. Offshore Wind Outlook 2019: World Energy Outlook Special Report. Offshore Wind 98 (2019).	Rejected. This section focuses on recent trends and future projections are covered in later parts of the chapter	Jan Wohland	ETH Zürich	Switzerland
17059	20	12	20	21	Costs of offshore wind (at least in Europe) are much lower than those in the figure. These sources providing time series often may not include recent data, but it would be useful to also depict some of the recent numbers in the graph, even if that is only for specific locations. Connect for example to Figure 6.14.	Accepted. Updated cost values now included and section moved to 6.4	Kornelis Blok	Delft University of Technology	Netherlands
6163	20	12	21	23	Using the data from IRENA on the evolution of costs of RES is questionable, and at least should be qualified. The most recent information comes from auctions, in which implicit subsidies are typically present, therefore artificially reducing the LCOE estimates.	Accepted. Section rewritten. Updated cost values now included and section moved to 6.4	Linares Pedro	Universidad Pontificia Comillas	Spain
17703	20	12	21	23	I was a bit confused - refer forward here to the graphic of PV cost declines by region (Fig 6.14) which seems more informative, also illustrating its wide regional dispersion. ANd/or the authors might consider a chart showing how the compatitive position of PV and coal has changed in the past 4 years in different countries, along the lines of Figure 6 of Bloomberg/CFLI (2019), Financing the Low-Carbon Future A Private-Sector View on Mobilizing Climate Finance, Climate Finance Leadership Initiative, https://data.bloomberglp.com/company/sites/55/2019/09/Financing-the-Low-Carbon-Future_CFLI-Full-Report_September-2019.pdf Accessed: 25th November 2019	Accepted. Section rewritten. Updated cost values now included and section moved to 6.4. regional differences dcisussed in new text.	Michael Grubb	UCL - Institute of Sustainable Resources	United Kingdom (of Great Britain and Northern Ireland)
19889	20	12	21	23	Box article should present not only cost reduction of various REs but also their relative competitiveness to conventional energy sources. In addition, as presented in Figure 6.10 of WEO 2019, relative competitiveness of solar amd wind differs across the regions. Such diversity should also be presented here.	Accepted. Section rewritten. New figure now in 6.4 includes cost of fossil.	Takahiko Tagami	Institute of Energy Economics, Japan	Japan
46079	20	12	21	23	PV cost are quite outdated in IAMs, therefore many major conclusions are strongly negatively affected. See Krey et al. (https://www.sciencedirect.com/science/article/pii/S0360544218325039) summarizing the PV cost in all relevant IAMs and then Vartiainen et al. (https://onlinelibrary.wiley.com/doi/full/10.1002/pip.3189), this leads to a factor 4 difference in PV cost in 2050 (or more) – and we are talking on the most relevant energy supply technology globally	Accepted. Covered in section 2.5.	Neven Duic	University of Zagreb	Croatia
15623	20	12	47	3	In Box 6.3 bioenergy is considered mature technology with LCOE that does not seem to decrease further. On p47 line 1-3 it is asserted tat the cost would decrease 30-50% in the next 3 decades. A consistent evaluation is needed.	Taken into account. We have made detailed reference to this in section 6.4.2.6 i.e. the distinction between the use of traditional and modern biomass. Traditional biomass has been utilized over a large time in developing countries and of course does not represent a limited scope for cost reductions. Whereas modern biomass may be used in industrial heat or biofuels. In these sectors, technological development may drive down costs.	Cheah Singfoong	Independent consultant, formerly more than 10 years with the National Renewable Energy Laboratory, USA	United States of America

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33259	20	12			Box 6.3 The graphs are only presenting LCOE and costs. In the introductory chapter, an other graph is used from irena which shows cost and capacity then LCOE. This is an illustration of the intermittence of these REN which is an issue to be address in system intégration. Finally done in the detail section by technology.	Accepted. Section 6.5 now covers system integration costs extensively.	Marc Darras	Association 4D	France
45053	20	13	20	13	LCOE was already defined	Accepted.	Ziv Hameiri	The University of New South Wales	Australia
4877	20	14	20	14	The use of "remained competitive" is not accurate. Rather, they manifested their or further increased in competitiveness (triggering energy utilities to promise ever higher shares of RES in future electricity generation portfolios). Also since fossil based electricity generation has gotten more expensive.	Accepted. Section rewritten. Updated cost values now included and section moved to 6.4	Patrick Lamers	National Renewable Energy Laboratory	United States of America
15141	20	15	20	15	Highly recommend adding hydropower: 'Hydropower has the lowest LCOE among all energy technologies according to IRENA (Renewable Power Generation Costs in 2017)', especially as you mention hydropower later on.	Accepted. Section rewritten. Updated cost values now included and section moved to 6.4	Aleksandr Kraevoy	UC RUSAL	Russian Federation
18681	20	15	20	15	use a date range rather than 'past five year'	Accepted. Section rewritten	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
37971	20	19	20	20	The labels for onshore wind, hydropower and bioenergy should have more different colours in the box 6.3, Fig 1 to assist better readability	Accepted. Section rewritten. New figure now in 6.4	Atle Harby	SINTEF Energy Research	Norway
28861	20	19	21	3	I think the Figure 1 and Figure 2 in Box 6.3 are the same?	Reject. One was kwH and other was kw. New figures now in 6.4.	Marissa Malahayati	National Institute for Environmental Studies	Japan
24321	20	20	20	20	Does the estimation in LCOE takes into account the public subsidies ? It is a bit difficult to tell and this graph is misleading.	Noted. Cost values in updated sectoin do not inlcude subsidies.	Alan BURLOT	Commissariat à l'énergie atomique et aux énergies alternatives	France
28443	20	20	20	20	box 6.3 ought to include the dramatic decrease in LCOE of waves and tides - however perhaps omiited due to the negligable global market share in renewables?	Rejected. Per the reviewers comments, it has not been included due to neglible market share and expectation that this willcontinue.	Matt Lewis	Bangor University	United Kingdom (of Great Britain and Northern Ireland)
31409	20	20	20	20	Please update the figure title: What we see is LCOE, isn't it?	Accepted. Section rewritten. New figure now in 6.4	Patrick Jochem	German Aerospace Center (DLR)	Germany
43683	20	20			Is it possible to display more information in this and the follown graph? There are huge country-level differences mostly based in soft and administrative costs, etc. Figure 2 in Creutzig et al 2017 Nature Energy has more information for PV (albeit also this data would need some updating with 2020 numbers)	Accepted. New graphs created. Regional differences now dsicussed in 6.4.	Felix Creutzig	MCC Berlin	Germany
9527	20	21	21	2	differentiate captions of Figures, now identical.	Accpeted. New figures now included in 6.4.	Tom Kram	PBL (Fellow)	Netherlands
1215	20	21			Provide reference	Accepted. Refrences now included in section 6.4.	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
19609	20	21			it hard to distingnish the lines of Hydropower and Bioenergy, due to the similar color in Figure1 and Figiure2 in box6.3	Accepted. New graphs created in 6.4.	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	China
16523	21	1			"Figure 2 Technology wise evolution of RE based electricity costs" shoud be better changed to "Figure 2 Technology wise evolution of RE based investment costs"	Dropped during revision. This figure and the box on RE costs was dropped from section 6.3 and a detailed discussion on RE costs in now included in section 6.4	Lining WANG	Economics and Technology Research Institute, CNPC	China
31411	21	2	21	2	Again, please improve the figure title	Accepted. New graphs and titles created in 6.4.	Patrick Jochem	German Aerospace Center (DLR)	Germany
45055	21	4	21	4	LCOE was already defined	Accpeted. Text revised.	Ziv Hameiri	The University of New South Wales	Australia
10085	21	4	21	7	not centered, not bold	Noted.	Maria E. Mondejar	Technical University of Denmark	Sweden
20339	21	8	21	23	dedicated literature knowledge for real solar PV cost and latest trends is missing, while available prominently in literature. Leading European PV experts have summarised the cost trends for Europe in the leading scientific PV journal (https://onlinelibrary.wiley.com/doi/full/10.1002/pip.3189) - BTW it is the most ever discussed article in social media of the leading PV journal; while leading global PV experts have done the same on the global scale twice in Science (https://science.sciencemag.org/content/364/6443/836 ; https://science.sciencemag.org/content/356/6334/141), such peer-reviewed literature for solar PV is a must in such a chapter and section!	Accepted. Section rewritten. Updated cost values now included and section moved to 6.4. regional differences dcisussed in new text.	Christian Breyer	LUT University	Finland
37979	21	11	21	12	add "water" to the sentence	Accpeted. text revised, now in 6.4	Atle Harby	SINTEF Energy Research	Norway
36727	21	14	21	15	"while corresponding costs in EU are one of the highest due to poor resources of solar and wind energy." This completely contradicts the systematically collected data shown in Fig. 1.6 in chapter 1. LCOE in Germany is nearly as low as in China, same in Italy and other EU countries not shown in Fig. 16 - and last but not least in Australia.	Accepted. Section rewritten. Updated cost values now included and section moved to 6.4. regional differences dcisussed in new text.	Pietro Altermatt	R&D Center of Trinasolar	Germany

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
26109	21	14	23	15	It is not clear what "$340/kWh" and "$175/kWh" are indicating. ($340/kWh is for present stationary systems? but what is $175 for?)	Text revised. $175/kWh was supposed to indicate future price but these numbers were dropped during revision in SOD. More detailed discussion on storage and related costs can be found in section 6.4.3	Keiichiro Sakurai	National Institute of Advanced Industrial Science and Technology	Japan
5713	21	15	21	15	Refers to costs in the EU being high due to poor resources of solar and wind energy. The EU covers a very large range of latitudes - solar is NOT poor in resource in (say) Southern Italy, Greece, Spain, etc. Wind is quite good in the UK, because offshore is coming down rapidly in price (I'm going to lump the UK in with the EU, but you might refer to "Europe" rather than the EU).	Accepted. Section rewritten. Updated cost values now included and section moved to 6.4. regional differences dcisussed in new text.	paul fennell	Imperial College	United Kingdom (of Great Britain and Northern Ireland)
34205	21	18	21	18	maybe precise "high proportion of variable sources, to be consistent with SRREN or many other works	Taken into Account. This Box has been removed, and all cost information has been moved to 6. where it can be treated more deeply.	Antoine BONDUELLE	Climate Action Network France	France
36729	21	18	21	19	"Finally, the costs of electricity storage are crucial for integrating intermittent sources like solar and wind in utility-scale electricity systems". Again wrong. It is not a matter whether the PV power is generated in utility-scale or not, but how deep the electrification with renewable sources is. Apart from Australia, there is hardly any region (yet) that has surplus of renewable power.	Taken into Account. This Box has been removed, and all cost information has been moved to 6. where it can be treated more deeply.	Pietro Altermatt	R&D Center of Trinasolar	Germany
20341	21	18	21	23	battery cost numbers are highly outdated - costs decline by 10-15% per year and the only reference is from 2015!? Latest cost numbers for utility-scale battery plants are summarised and discussed by Vartiainen et al. (https://onlinelibrary.wiley.com/doi/full/10.1002/pip.3189)	Taken into Account. This Box has been removed, and all cost information has been moved to 6. where it can be treated more deeply.	Christian Breyer	LUT University	Finland
37393	21	18	21	23	description of fall of costs of battery storage seems not up to date, with a 2015 (!) paper cited.	Taken into Account. This Box has been removed, and all cost information has been moved to 6. where it can be treated more deeply.	Michiel Schaeffer	Climate Analytics	Netherlands
37981	21	20	21	20	add "grid-connected" in front of the "electricity storage"	Taken into Account. This Box has been removed, and all cost information has been moved to 6. where it can be treated more deeply.	Atle Harby	SINTEF Energy Research	Norway
37983	21	20	21	20	I suggest to add this sentence after "...electricity storage". "In addition, storage hydropower provides a large and not known potential to store electricity in the form of water not yet transformed to electricity". It is important to consider the role of hydropower as a dispatchable renewable very well suited to intergrate wind and solar energy	Taken into Account. This Box has been removed, and all cost information has been moved to 6. where it can be treated more deeply.	Atle Harby	SINTEF Energy Research	Norway
26107	21	20	21	23	The quoted cost for Li-ion battery packs (<$410/kWh@2015) is outdated. Nykvist has a newer publication in 2019 (https://doi.org/10.1016/j.enpol.2018.09.035) with a cost close to $200/kWh@2017. Note: BNEF reports $156/kWh@2019 (https://about.bnef.com/blog/battery-pack-prices-fall-as-market-ramps-up-with-market-average-at-156-kwh-in-2019/).	Taken into Account. This Box has been removed, and all cost information has been moved to 6. where it can be treated more deeply.	Keiichiro Sakurai	National Institute of Advanced Industrial Science and Technology	Japan
8819	21	21	21	23	Source and data provided are rather old and do not capture the latest developments in battery storage system costs (and information should be made more consistent with what is presented in section 6.3.7)	Taken into Account. This Box has been removed, and all cost information has been moved to 6. where it can be treated more deeply.	Saygın Değer	SHURA Energy Transition Center	Turkey
12887	21	21	21	23	The storage component reduction in terms of LCOE may also be brought out.	Taken into Account. This Box has been removed, and all cost information has been moved to 6. where it can be treated more deeply.	ASHOK NEMA	Nuclear Power Corporation of India Limited	India
36731	21	21	21	23	"according to a study, between 2007 and 2014". To judge battery prices only until 2014 is not acceptable scientific practice. Sorry, this is lay writing. Cost for Li batteris has fallen from 2014 to now substantially. This is not acceptable practice. To state battery prices from 2015 in a report like this borders to manipulation.	Taken into Account. This Box has been removed, and all cost information has been moved to 6. where it can be treated more deeply.	Pietro Altermatt	R&D Center of Trinasolar	Germany
45365	21	21	21	23	Cost of LiIon has fallen substantially since 2014 so this mischaracterizes current markett conditions. BNEF's 2019 Battery Price Survey shows "BNEF's 2019 Battery Price Survey" https://about.bnef.com/blog/battery-pack-prices-fall-as-market-ramps-up-with-market-average-at-156-kwh-in-2019/ - other analyst reports are in line with this.	Taken into Account. This Box has been removed, and all cost information has been moved to 6. where it can be treated more deeply.	Deborah Knuckey	Published energy journalist plus consultant for renewable energy development and finance companies through Kiterocket	United States of America
31801	21	22	21	23	It may be useful to cite many other studies that predict future Li-ion and other battery prices which are expected to fall to USD 100 / kWh by mid to late 2020s	Taken into Account. This Box has been removed, and all cost information has been moved to 6. where it can be treated more deeply.	Ashok Sreenivas	Prayas (Energy Group)	India
39169	21	22	21	23	For a more recent reference on Li-ion battery pack costs, see https://doi.org/10.1002/pip.3189, which quotes BNEF on an average battery pack cost of 176 USD/kWh in 2018.	Taken into Account. This Box has been removed, and all cost information has been moved to 6. where it can be treated more deeply.	Tom Brown	Karlsruhe Institute of Technology	Germany
34207	21	23	21	23	for batteries, a 2015 reference could be replaced by the last IRENA report of 2019	Taken into Account. This Box has been removed, and all cost information has been moved to 6. where it can be treated more deeply.	Antoine BONDUELLE	Climate Action Network France	France
5883	21	23			This 2015 reference is well out-date given the trends for battery manufacturing and cost reductions. This, and all references, need to provide information that is right up to date.	Taken into account. Latest literature was cited in revised text	Ralph Sims	Massey University	New Zealand

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
32257	21	24	21	24	I propose to change the title and to explicitely quote nuclear, CCUS and geothermal energy	Rejected. This subsection was updated to include the progress on hydropower, bioenergy and marine. The purpose here is to capture recent trends with detailed discussion on low-carbon fuels and technologies in section 6.4	Jean-Guy Devezeaux de Lavergne	Commissariat à l'Energie Atomique et aux Energies Alternatives	France
34077	21	24	21	24	providing a graph with nuclear cost evolution could be useful	Rejected due to space constraint. More detailed discussion on nuclear in section 6.4	Antoine BONDUELLE	Climate Action Network France	France
35383	21	24	21	24	providing a graph with nuclear cost evolution could be useful	Rejected due to space constraint. More detailed discussion on nuclear in section 6.4	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France
32259	21	24	22	35	I do not understand why the (may be) most accurate body on nuclear (ie the OECD/NEA) is cited only once	Noted. A section dedicated to nuclear is 6.4.2.4	Jean-Guy Devezeaux de Lavergne	Commissariat à l'Energie Atomique et aux Energies Alternatives	France
37985	21	24	23	2	This chapter is missing the largest low-carbon energy source: Hydropower. Should be included	Partially accepted. Statistics on recent trends in hydropower added. However, more detailed discussion can be found in section 6.4.2.3	Atle Harby	SINTEF Energy Research	Norway
15143	21	24	23	3	In the subsection 6.3.6 Limited deployment of low-carbon energy sources beyond solar and wind power, only nuclear energy is considered. Highly recommend considering and adding information about the hydropower since it is expected to remain the world's largest source of renewable electricity generation and play a critical role in decarbonising the power system and improving system flexibility (as per IEA, December 2019)	Partially accepted. Revised text now covers trends in hydropower, bioenergy, marine, geothermal and CCS. Statistics on recent trends in hydropower added. However, more detailed discussion can be found in section 6.4.2.4	Aleksandr Kraevoy	UC RUSAL	Russian Federation
33263	21	24			§ 6.3.6 should end by a review of progress on modern biomass and on biogas. Even if such technologies do not represent an important amount of énergy presently, they are important for the future, and may be part of transformation in many countries.	Partially accepted. Short discussion on recent trends in bioenergy added. However, more detailed discussion can be found in section 6.4.2.3	Marc Darras	Association 4D	France
8875	21	25	21	26	The study mentioned here should be documented and and referenced. There is no consensus on the figures given in the draft report.	Taken into account. Citations added whereever necessary	Michel SIMON	Vice Président SFENRAL	France
31413	21	25	21	26	It would be good to introduce the LCA approach here and be more concrete on the emissions from PV, wind etc.	Noted. More detailed analysis of the low carbon energy sources in covered in Section 6.4	Patrick Jochem	German Aerospace Center (DLR)	Germany
36741	21	25	21	26	"most of this growth has been in wind and solar power." A suitable citation here is: Amory B. Lovins, Titiaan Palazzi, Ryan Laemel, Emily Goldfield, "Relative deployment rates of renewable and nuclear power: A cautionary tale of two metrics", Energy Research & Social Science 38 (2018) 188–192.	Taken into account. Citation included along with other references	Pietro Altermatt	R&D Center of Trinasolar	Germany
16259	21	25	22	35	In the text giving background information related to nuclear power, consider adding a paragraph that discusses risk of nuclear arms proliferation related especially to new nuclear power in the 29 "newcomer" states. See, for example, Goldemberg, J., 2009. Nuclear energy in developing countries. Daedalus, 138(4): 71-80. Notably missing from plans for adopting nuclear power in a widespread fashion to address climate change is a new international mechanism that would identify the most nuclear-arms-proliferation-resistant pathway and require that this pathway be followed. The current Non-Proliferation Treaty was not adopted to address climate change, and its utility is not up to the task. For example, Saudi Arabia is presently developing facilities for nuclear materials enrichment to fuel its planned new nuclear power program, and this may be a pretext for nuclear arms production.	Noted. A section dedicated to nuclear is 6.4.2.4	Daniel Helman	College of Micronesia-FSM	Micronesia, Federated States of
17151	21	25	22		Add a discussion of marine energy and its stage of development/deployment	Partially accepted. Statistics on recent trends in marine energy added. However, more detailed discussion can be found in section 6.4.2.9	Deborah Greaves	University of Plymouth	United Kingdom (of Great Britain and Northern Ireland)
5885	21	25		29	No evidence for these broad statements that are also misleading. Need to rewrite with references - but also partly covered above. Could delete this para.	Taken into account. Text revised with relevant citations	Ralph Sims	Massey University	New Zealand
694	21	26	21	26	"Nuclear power has been declining". To say something like that, it is necessary to define a period. It is certainly not true over the industrial period. In the past 20 years, it has been rather constant, There was a sharp decrase after the Fukushima accident, but a steady growth since then.	Accepted. Text revised.	Francois-Marie Breon	CEA	France
8873	21	26	21	27	You mention: "Nuclear power has been declining and faces a number of obstacles to more widespread deployment" What is the source?. To be objective, it might be stated that nuclear has declined after Fukushima accidnt, but is at a steady level since 2015, that 55 units are under construction and more than 150 are in project phase.	Taken into account. Text revised with appropriate citations	Michel SIMON	Vice Président SFENRAL	France
45415	21	26	21	27	Sentence says that nuclear has been decling, but should specify that it's share of electricity or energy has been declining. As the total generation has been steadily increasing, with oly a slight dip after Fukushima, which has since rebounded.	Taken into account. Text revised with appropriate citations	Jessica Lovering	Carnegie Mellon University	United States of America
23913	21	27	21	27	bioenergy production is not included	Missing data now added in SOD	Stefan Majer	German Biomass Research Centre - DBFZ	Germany

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
34381	21	27	21	27	CCUS should be replaced by CCS.	This has been updated to CCS along with the full form as we are talking about it carbon capture and storage in general. The section here now covers recent trends in CCS deployment and a more detailed discussion is covered in section 6.4.	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
28863	21	27	21	28	"Bioenergy production has 28 grown from xx% to yy% over the last decade" how much is xx and yy	Missing data now added in SOD	Marissa Malahayati	National Institute for Environmental Studies	Japan
20343	21	27			CCUS' is a highly misleading wording and requires major revision. Correct is to separate 'CCU' and 'CCS'. These two aspects are COMPLETELY different, since CCU describes the reuse of CO2 (for point sources), while even CO2 direct air capture is included as DACCU. CCU of renewables sources (e.g. pulp & paper industry, or renewable energy based DAC) is part of a zero GHG emission system and also required earlier throughout the transition. CCS is used later, in particular for negative CO2 emissions. Literature for a clear separation are 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). This entire chapter requires major revision in separation of CCUS. Please also notice that many use Power-to-X (PtX) synonoumus to CCU (see also Breyer et al. for that), this should be better reflected in the entire chapter.	This has been updated to CCS along with the full form as we are talking about it carbon capture and storage in general. The section here now covers recent trends in CCS deployment and a more detailed discussion is covered in section 6.4.	Christian Breyer	LUT University	Finland
6029	21	28	21	28	Percentage of growth for bioenergy production not indicated	Missing data now added in SOD	SAIK PENG, CASEY NGO	R-SYNC TECHNICAL RESOURCES SDN. BHD.	Malaysia
6349	21	28	21	28	figures for Bioenergy production are missing. Please add	Missing data now added in SOD	Sciacovelli Adriano	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
12889	21	28	21	28	xx% and yy% may be replaced by actual values	Missing data now added in SOD	ASHOK NEMA	Nuclear Power Corporation of India Limited	India
13843	21	28	21	28	Suggestion of missing values : "Bioenergy share in Total Primary Energy Supply has grown from only 9.3 % in 2007 to 9.5% in 2017. (1.12 Gtoe out of 12.08 Gtoe in 2007 vs 1.33 Gtoe out of 14.03 Gtoe in 2017 source : IEA World Energy Balances 2019 accessible online : https://www.iea.org/data-and-statistics/data-tables?country=WORLD&energy=Balances&year=2007)	Taken into consideration. Missing values and description added to SOD	Alexandre Bizeul	International Energy Agency	France
15047	21	28	21	28	bioenergy production need to be given	Missing data now added in SOD	Béla Munkácsy	ELTE University	Hungary
31415	21	28	21	28	Please update the xx etc.	Missing data now added in SOD	Patrick Jochem	German Aerospace Center (DLR)	Germany
45367	21	28	21	28	Potential source for missing data: https://worldbioenergy.org/uploads/191129%20WBA%20GBS%202019_LQ.pdf	Taken into consideration. Missing values and description added to SOD	Deborah Knuckey	Published energy journalist plus consultant for renewable energy development and finance companies through Kiterocket	United States of America
2147	21	28			percentages need to be added	Missing data now added in SOD	Amy Townsend-Small	University of Cincinnati	United States of America
17149	21	28			replace xx and yy with numbers	Missing data now added in SOD	Deborah Greaves	University of Plymouth	United Kingdom (of Great Britain and Northern Ireland)
19611	21	28			"grown from xx% to yy% over the last decade" need to input number	Missing data now added in SOD	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	China
38067	21	28			For bioenergy growth over last decade, see https://www.iea.org/fuels-and-technologies/bioenergy	Taken into consideration. Missing values and description added to SOD	Craig Jamieson	Straw Innovations Ltd	Philippines
41985	21	28			"xx and "yy"	Missing data now added in SOD	Francisco Javier Hurtado Albir	European Patent Office	Germany
44767	21	30	21	31	The IAEA 2019a reference in the first sentence could be replaced with IAEA PRIS database which is managed from the IAEA and gives more up to date numbers for number of reactors, total net capacity, and number of reactors under construction: https://pris.iaea.org/PRIS/home.aspx	Noted. The figures wil be updated. The most up to date source on the status of new constructions, grid connections, decommissioning is: https://pris.iaea.org/PRIS/home.aspx	Daniel Westlén	Liberal party Swedish parliament	Sweden
35385	21	30	21	32	According to the reference synthesis World Nuclear Industry Status Report, as of the 1st January 2020, 415 reactors were actually operating, accounting for a total net installed capacity of 370 GW(e), while 27 are in long-term outage https://www.worldnuclearreport.org/World-Nuclear-Reactor-Status-as-of-1-January-2020-with-dataviz.html	Noted. The figures wil be updated. The most up to date source on the status of new constructions, grid connections, decommissioning is: https://pris.iaea.org/PRIS/home.aspx	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France

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20345	21	30	22	35	any word on the disastrous nuclear economics is missing, which is misleading and leads to ignorance for readers. Latest nuclear economic challenges can be found in Ram et al. (https://www.sciencedirect.com/science/article/pii/S0959652618321486) and Schneider et al. (https://www.worldnuclearreport.org/IMG/pdf/wnisr2019-v2-lr.pdf)	Noted. A section dedicated to nuclear is 6.4.2.4	Christian Breyer	LUT University	Finland
45369	21	31	21	32	Missing word in first phrase? "Despite historically the highest available power, the share of nuclear power in total electricity production"	Noted. This text was removed during revisions	Deborah Knuckey	Published energy journalist plus consultant for renewable energy development and finance companies through Kiterocket	United States of America
45371	22	2	22	3	Amend "a surge of electricity demand in developing countries, which, to a large extent, was met by fossil fuels." to "a surge of electricity demand in developing countries, which, to a large extent, was met by ADD CAUSE fossil fuels." rapidly deployable? Lower capital cost? Otherwise a surge in developing-nation demand doesn't explain why the slow down occured	Accepted. Text Revised.	Deborah Knuckey	Published energy journalist plus consultant for renewable energy development and finance companies through Kiterocket	United States of America
34079	22	3	22	4	It is worth noting that many advanced economies using nuclear power are phasing out their fleet, including France for about a third of its capacity, Germany and Belgium for the whole fleet.	Accepted. Text Revised.	Antoine BONDUELLE	Climate Action Network France	France
35387	22	3	22	4	It is worth noting that many advanced economies have decided to phase out nuclear energy or to reduce its share. Even in France, the share of nuclear power is supposed to drop from 75% to 50% by 2035.	Accepted. Text Revised.	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France
28865	22	4	22	5	"The bulk of nuclear reactors (50%) is located in the USA (96), France (58), Japan (37) and Russia (36)." What is the value inside the brackets?	These were number of reactors. This text was dropped during revision.	Marissa Malahayati	National Institute for Environmental Studies	Japan
5887	22	4			How can "the bulk of" equate to 50%? Reword.	Taken into account during text revision	Ralph Sims	Massey University	New Zealand
18607	22	5	22	5	As France is decommissioning the Fessenheim nuclear power plant, you may want to update the number of operational power plants from 58 to 57 (to the end of June 2020) or to 56 (from July 2020 onwards).	Noted. The figures wil be updated. The most up to date source on the status of new constructions, grid connections, decommissioning is: https://pris.iaea.org/PRIS/home.aspx	Thomas Gibon	Luxembourg Institute of Science and Technology (LIST)	France
34081	22	5	22	5	Presently, most of Japanese reactors are in long-terme outage.	Noted.	Antoine BONDUELLE	Climate Action Network France	France
35389	22	5	22	5	As of January 2020, 24 out of 27 Japanese reactors are in long-terme outage.	Noted.	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France
34083	22	6	22	8	"assessments have established" is misleading. In the case of France, Authorities such as ASN (safety) or IRSN (expertise) are far from any rulemaking on 50 and 60 years and are still studying this. Even if they accept, their prescriptions could hamper most of the economic benefits for delaying closures.	Rejected. Text refers to many reactors not all of them. (Eighty-eight of America's 96 reactors have received approval of their first 20-year extension)	Antoine BONDUELLE	Climate Action Network France	France
34085	22	6	22	8	This part is misleading, because only two commercial reactors in the world have been running over 50 years, this does not constitute "proof".	Rejected. 89 reactors worldwide have more than 40 years (nominal design lifetime is 40 years). https://pris.iaea.org/PRIS/WorldStatistics/OperationalByAge.aspx	Antoine BONDUELLE	Climate Action Network France	France
35391	22	6	22	8	The sentence "engineering assessment have established" is controversial. Some key components like the vessel (designed on a 40-years use hypothesis according to the French Nuclear Safety Authority (ASN)) can be neither repaired nor refurbished. The French nuclear safety authority (ASN) and the French Institute for Radioprotection and Nuclear Safety (IRSN) are still documenting the effects of ageing on such components and do not take the 10-years lifetime extension after 40 years for granted for any reactors (see https://www.irsn.fr/FR/connaissances/Installations_nucleaires/Les-centrales-nucleaires/visites-decennales/Reexamen-900/Pages/5-Reexamen-de-surete-reacteurs-900-MWe-FAQ.aspx#.Xlzw8hdCcU8).	Rejected. Text refers to many reactors not all of them. (Eighty-eight of America's 96 reactors have received approval of their first 20-year extension)	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France
37395	22	6	22	8	Lifetime extensions have gone beyone engineering assessments and are becomming more common, in, e.g., the United States. Multiple plants have receieved 60-year licensens, with some even receiving 80-year license extensions (Turkey Point 3&4, https://www.nrc.gov/reactors/operating/licensing/renewal/subsequent-license-renewal.html).	Noted.	Michiel Schaeffer	Climate Analytics	Netherlands
15049	22	7	22	7	"NNP" - the only abreviated mentioning of nuclear. Is it neccessary to use?	Taken into account. Abbreviation dropped during revision	Béla Munkácsy	ELTE University	Hungary
32261	22	7	22	7	Clearly no one nuclear power designer does intend now to limit the operation lifetime to 40 years. Generally, 60 years are today the lower limit. Thus, the text is not precise, because it could explain: "past (or generation II) reactors where generally design for a life time in thge range of 40 years..."	Noted.	Jean-Guy Devezeaux de Lavergne	Commissariat à l'Energie Atomique et aux Energies Alternatives	France

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
35393	22	7	22	10	As of today, only two reactors in the world have been running over 50 years, which is not enough to generalise the possibility of lifetime extension to the global nuclear fleet	Rejected. 89 reactors worldwide have more than 40 years (nominal design lifetime is 40 years). https://pris.iaea.org/PRIS/WorldStatistics/OperationalByAge.aspx	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France
36743	22	8	22	9	"…but engineering assessments have established that many can operate safely for longer…" This is not a scientific formulation of safety. I suggest you cite: Spencer Wheatley, Benjamin Sovacool, and Didier Sornette, "Of Disasters and Dragon Kings: A Statistical Analysis of Nuclear Power Incidents and Accidents", Risk Analysis 37, 99 - 115 (2017), DOI: 10.1111/risa.12587. I suggest to write instead: "but engineering assessments indicate that many can operate under the same safety requirements for longer…". Safety is a measure of what is required by government regulations.	Noted.	Pietro Altermatt	R&D Center of Trinasolar	Germany
36733	22	10	22	11	"… but are one of the most cost-effective ways to provide low-carbon sources of electricity through to 2040". This is in stark contradiction to Fig. 1.6 in Chapter 1. And nuclear power is subsidies in many different ways that make it difficult to quantify realistic pwoer cost. I suggest to remove that sentence.	Rejected. Fig 1.6 in Ch 1 refers to LCOE of commericial PV only. In addition, discussion on life time extension of nuclear power has been moved to 6.4.2.4, which is a dedicated section for nuclear energy.	Pietro Altermatt	R&D Center of Trinasolar	Germany
27913	22	10	22	12	IPCC states, "Lifetime extensions require significant investment (in the range of USD 750-1200 per kW) but are one of the most cost-effective ways to provide low-carbon sources of electricity through to 2040." This statement is contradicted entirely by the published paper, Cebulla, F., and M.Z. Jacobson, Alternative renewable energy scenarios for New York, Journal of Cleaner Production, 205, 884-894, 2018, which finds that subsidizing nuclear reactors instead of using the subsidy to purchase renewables to replace fossils drives up CO2 emissions. Please include this reference and the conclusion, since it is a running myth that keeping nuclear plants that require subsidy open serves a benefit. Only nuclear plants that do not require subsidy can stay open. Those that require subsidy should be retired.	Rejected. The text here refers to life time extension beyond their typical lifetime of 40 years not about subsidising nuclear power to stay competitive in the market.	Mark Jacobson	Stanford University	United States of America
34087	22	10	22	12	It can be suggested to balance this data with other sources than intergovernmental reports from IAEA or IAE studies, which are not peer-reviewed.	Noted. These are well recognized bodies, and their publications are reviewed by a number of experts. Please provide peer-reviewed literature to support your arguments.	Antoine BONDUELLE	Climate Action Network France	France
34089	22	10	22	12	The whole part of the report is not consistent with the best source available, namely the Cour des Comptes (French State Audit) on lifetime extension (e.g. 100 000 M€ for the 58 French reactors or 1582€/kW) : https://www.ccomptes.fr/fr/documents/1134. Please correct the bracket with such figures.	Rejected. Page 212 from the cited report . "EDF a évalué les ordres de grandeur des dépenses d'investissement à prévoir pour le parc dans les 15 ans à venir à 50 Md€2010, soit 58 Md€ courants non actualisés, avec des hypothèses d'inflation comprises suivant les années entre 1,5 % et 2 %". It is not corresponding to the 100 billions 2016.	Antoine BONDUELLE	Climate Action Network France	France
34091	22	10	22	12	The sentence « lifetime extensions are one of the more cost-effective ways to provide low-carbon sources of electricity » is not proven and is contradicted with other parts of this chapter. RE is clearly more competitive than many existing reactors in the US and eleswhere.	Noted.	Antoine BONDUELLE	Climate Action Network France	France
34093	22	10	22	12	A more cost effective use of the money is to close old reactors and choose instead renewable energies and efficiency. This part is misleading policymakers.	Noted.	Antoine BONDUELLE	Climate Action Network France	France
35395	22	10	22	12	It should be necessary to balance this data with other sources than the IEA studies, which are not peer-reviewed.	Noted. These are well recognized bodies, and their publications are reviewed by a number of experts. Please provide peer-reviewed literature to support your arguments.	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France
35397	22	10	22	12	The given data is not consistent with the official estimates of the French Audit Office (Cour des Comptes) concerning lifetime extension (100 billions€2016 for the lifetime extension of the whole 63,2 GW nuclear fleet, that is to say 1582 €2016 per kW) : https://www.ccomptes.fr/fr/documents/1134. Even without taking into account the variation between €2016 and €2020, this would mean some 1770 USD2020, much more than the upper part of the given bracket.	Rejected. Page 212 from the cited report . "EDF a évalué les ordres de grandeur des dépenses d'investissement à prévoir pour le parc dans les 15 ans à venir à 50 Md€2010, soit 58 Md€ courants non actualisés, avec des hypothèses d'inflation comprises suivant les années entre 1,5 % et 2 %". It is not corresponding to the 100 billions 2016.	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France
35399	22	10	22	12	The assertion « lifetime extensions are one of the more cost-effective ways to provide low-carbon sources of electricity » is at odds with the closure of many ageing plants, which have became uncompetitive compared to cheaper energy sources (including renewable energies). According to the Union of Concerned Scientists (2018), about 35% of the US nuclear plants would be unprofitable : https://www.ucsusa.org/resources/nuclear-power-dilemma	Noted	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France
35401	22	10	22	12	According to respected sources such as the World Nuclear Industry Status Report (Schneider M. et al., World Nuclear Industry Status Report 2019, Mycle Schneider Consulting, Paris, Budapest), in some cases, closing most ageing nuclear plants and investing in cheaper renewable energies and/or energy conservation instead would be a more cost-effective way to reduce emissions than lifetime extension.	Noted	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France
35403	22	10	22	12	Lifetime extension can only be considered as a short-term and provisional way to provide low-carbon electricity. Extending the lifetime of a plant for one or two decades will thus require important investments while resulting in postponing the implementation of more lasting and effective decarbonization options.	Noted	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France

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15051	22	11	22	11	and most risky	Noted	Béla Munkácsy	ELTE University	Hungary
36735	22	11	22	12	Citation of EPA 2019 is missing on page 140.	Taken into account. Text revised.	Pietro Altermatt	R&D Center of Trinasolar	Germany
34095	22	12	22	13	This is not only an economic issue. In France, lifetime extension through safety authorities (ASN) can be only for ten years at a time. The projections cannot be for granted.	Noted	Antoine BONDUELLE	Climate Action Network France	France
34097	22	12	22	13	This part should mention competition with other low carbon options	Noted. A section dedicated to nuclear is 6.4.2.4	Antoine BONDUELLE	Climate Action Network France	France
35405	22	12	22	13	Lifetime extension does not depend on national policies but on nuclear safety authorities decisions and operator choices. In France, lifetime extension can only be granted for a 10-years-period, which makes 20 years-extension-scenarios unreliable.	Noted	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France
35407	22	12	22	13	The contribution of nuclear power to GHG emission will become growingly dependent on its competitiveness compared to other low-carbon technologies. A recent publication from Lazard (november 2019) comparing LCOE for different low-carbon sources underlines that existing nuclear power is now less competitive than wind energy and utility-scale solar : https://www.lazard.com/media/451086/lazards-levelized-cost-of-energy-version-130-vf.pdf	Noted. A section dedicated to nuclear is 6.4.2.4	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France
34099	22	14	22	14	Most constructions are facing delays, thus the figures given are misleading. There should be a distinction between "old construction sites" and "recent ones"	Noted. A section dedicated to nuclear is 6.4.2.4	Antoine BONDUELLE	Climate Action Network France	France
35409	22	14	22	14	This data is not consistent with those mentioned by the World Nuclear Report (Schneider, 2019), according to which, by the 1st of July 2019, 46 units were in construction in 16 countries	Taken into account. The most up to date source on the status of new constructions, grid connections, decommissioning is: https://pris.iaea.org/PRIS/home.aspx	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France
35411	22	14	22	14	Considering the need to reduce emissions quickly, attention should be given to the delivering delay. According to the reference synthesis World Nuclear Industry Status Report (Schneider, 2019) quoting IAEA, about the half of the units under construction are experiencing delays and are not on schedule. 4 of them have been under construction for more than 10 years.	Noted. A section dedicated to nuclear is 6.4.2.4	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France
43555	22	14	22	14	There are 55 (or, as of Marhch 2020, in fact 53) nuclear units CLASSIFIED as "under construction" under IAEA rules, but the real situation is less optimistic. This statistic includes two units in Taiwan, as well as Baltic-1 unit in Russia and two units in Japan, where completion of at least one is quite uncertain. This perhaps should be noted.	Taken into account. The most up to date source on the status of new constructions, grid connections, decommissioning is: https://pris.iaea.org/PRIS/home.aspx	Adam Blazowski	FOTA4Climate.org	Poland
34681	22	14	22	25	Here should be specified that nuclear energy is not a carbon free energy source because Life Cycle Analysis from the mine to the residuals requires energy that comes from the fossil fuels so at the current stages, nuclear is not a zero emissions energy (). There should be emphasized the decomissioning expensive processes after the end life of the centrals. Moreover nuclear power requires also water (J Macknick and R Newmark and G Heath and K C Hallett. Operational water consumption and withdrawal factors for electricity generating technologies: a review of existing literature. Environmental Research Letters 2012. 10.1088/1748-9326/7/4/045802) (Sathaye, J., O. Lucon, A. Rahman, J. Christensen, F. Denton, J. Fujino, G. Heath, S. Kadner, M. Mirza, H. Rudnick, A. Schlaepfer, A. Shmakin, 2011: Renewable Energy in the Context of Sustainable Development. In IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation [O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlömer, C. von Stechow (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA)	Noted. A section dedicated to nuclear is 6.4.2.4	Jordi Solé-Ollé	Spanish National Research Council (CSIC)	Spain
34101	22	16	22	17	The countries quoted for "accession" are a wish list not relevant for an IPCC volume. Only four countries qualify in this part (Schneider et al. 2019): Bangladesh, Belarus, Turkey, United Arab Emirates.	Rejected. The text refers to countries at different stages of nuclear power programme / consideration.	Antoine BONDUELLE	Climate Action Network France	France
35413	22	16	22	17	Mentioning « considerations » is too broad and unclear.	Taken into account during text revision	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France
35415	22	16	22	17	According to the World Nuclear Report (Schneider, 2019), in 2018, only 4 new countries were actual newcomers building reactors for the first time : Bangladesh, Belarus, Turkey, United Arab Emirates.	Rejected. The text refers to countries at different stages of nuclear power programme / consideration.	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France
36745	22	16	22	17	After the sentence "There are also 29 "newcomer" countries…" I suggest that you mention time overruns and cost overruns of nuclear power compared to other power technologies, and that you take data from the two following references: AlexanderGilbert et al, "Cost overrunsand financial risk in the construction of nuclear power reactors: A critical appraisal", Energy Policy102(2017) 644–649; and: Benjamin K. Sovacool, Alex Gilbert, Daniel Nugent, "An international comparative assessment of construction cost overruns for electricity infrastructure", Energy Research & Social Science 3 (2014) 152–160, which may be outdated and be replaced by a more recent publication.	Noted. A section dedicated to nuclear is 6.4.2.4. Thanks for References.	Pietro Altermatt	R&D Center of Trinasolar	Germany

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36737	22	19	22	21	This is in stark contrast to what you described in paragraph 6.3.5 and to Fig. 1.6 in Chapter 1. You simply left our PV and wind in your arguments. Additionally, it lacks a citation.	Rejected. The text refers to a geographical shift for new builds for nuclear energy.	Pietro Altermatt	R&D Center of Trinasolar	Germany
32269	22	21	22	21	It could be usefull to precise "The cost share of uranium, gthe only component which can show a significant volatility, is in fact quite narrow, because around 5%. This leads in a very stable cost of of nujclear production, noticeably in the case of the existing reactors." See http://www.sfen.org/sites/default/files/public/atoms/files/note_-_les_couts_de_production_du_parc_nucleaire_francais_-_ppe_-_sfen.pdf	Noted. A section dedicated to nuclear is 6.4.2.4.	Jean-Guy Devezeaux de Lavergne	Commissariat à l'Energie Atomique et aux Energies Alternatives	France
34103	22	22	22	29	This part relies too exclusively on IAEA reports which are not peer reviewed in the same standard as the rest of the report. Preceding reports accepted intergovernmental littérature especially data, but did rely on a plurality of sources for projections and prospective.	Rejected. The text refers to the estimates of nuclear power in the future, which are rather conservative if we compare with other projections of other international organisations such as IEA. These are well recognised bodies and their publications are reviewed by a number of national and international experts. There is no peer-reviewed literature providing consistent projections for nuclear power.	Antoine BONDUELLE	Climate Action Network France	France
34105	22	22	22	29	Projections used here contradict other parts of this report. It infers that the bracket of growth is "stagnation-strong growth" when other sources say "slow decrease-stagnation". There is clearly a coherence issue here. Please note also that the references given do not match the scenarios used in the text there should be a more precise quote with page.	Noted.	Antoine BONDUELLE	Climate Action Network France	France
34107	22	22	22	29	Reactor construction has been declining for several years in a row and even in China no construction started in the last years. This is inconsistent with the optimistic message in this part of the report. The German phase-out and the decline of the fleet in France (both decided and ratified at State level) will come in full force during the period.	Rejected. The text refers to the estimates of nuclear power in the future, which are rather conservative if we compare with other projections of other international organisations such as IEA. These are well recognised bodies and their publications are reviewed by a number of national and international experts. There is no peer-reviewed literature providing consistent projections for nuclear power.	Antoine BONDUELLE	Climate Action Network France	France
35417	22	22	22	29	This data requires balancing by other sources that IAEA, whose reports are not peer-reviewed.	Rejected. The text refers to the estimates of nuclear power in the future, which are rather conservative if we compare with other projections of other international organisations such as IEA. These are well recognised bodies and their publications are reviewed by a number of national and international experts. There is no peer-reviewed literature providing consistent projections for nuclear power.	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France
35419	22	22	22	29	IAEA projections needs to be balanced since they generally tend to broadly over-estimate future development of nuclear power. It is to be reminded that in 2000, the global nuclear capacity was only one-tenth of the « most-likely » IAEA scenario designed in 1974.	Rejected. The text refers to the estimates of nuclear power in the future, which are rather conservative if we compare with other projections of other international organisations such as IEA. These are well recognised bodies and their publications are reviewed by a number of national and international experts. There is no peer-reviewed literature providing consistent projections for nuclear power.	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France
35421	22	22	22	29	These scenarios are not consistent with the current trend. As of 2020, the number of reactors in construction has been declining for the 6th year in a row and even the Chinese nuclear development plan remains below the ambitions of the 5-year-plan 2016-2020 (Schneider)	Noted	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France
35423	22	22	22	29	The technical feasability of such scenarios also depend on short construction time. However, the mean construction time of reactors generally tends to be higher than officially expected (even in China, reactors started during the last decade needed a mean time of 6 years to be completed and almost all of them experienced delays) (Schneider, 2019). Relying on massive nuclear newbuilt to provide low-carbon sources would therefore put the world at risk of not meeting climate goals if construction time keeps experiencing delays	Noted	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France
35425	22	22	22	29	The financial feasability of these scenarios should be disputed, since the cost of new nuclear plant has always been escalating (See Reinhard Haas et al., The Historical Development of the Costs of Nuclear Power, 2019, https://link.springer.com/chapter/10.1007/978-3-658-25987-7_5). The question is not only if required investments and adequate finance mechanism will be available, but also whether building nuclear plant will still make sense with regards of the shrinking costs of solar and wind capacities.	Noted	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France
35427	22	22	22	29	These projections require challenging to check if they are climate-change-proof. Rising sea level may put coastal plants at risk (see https://climatenewsnetwork.net/speeding-sea-level-rise-threatens-nuclear-plants/) whereas inland plants may be facing a decline of river flow.	Noted	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France

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35827	22	22	22	29	IAEA projection of world nuclear electrical generating capacity by 2050: increase to 715 GW(e) - ambitious but plausible and technically feasible ? YES ! Next generation of nuclear energy systems (Generation IV to be deployed commercially around 2040) Generation IV reactors are a set of theoretical nuclear reactor designs currently being researched. These designs are generally not expected to be available for commercial construction before 2040. Current reactors in operation around the world are generally considered second- or third-generation systems, with the first-generation systems having been retired some time ago. Research into these reactor types was officially started by the Generation IV International Forum (GIF) based on eight technology goals. The primary goals being to improve nuclear safety, improve proliferation resistance, minimize waste and natural resource utilization, and to decrease the cost to build and run such plants. GIF is a co-operative international endeavour which was set up around 2000 to carry out the research and development needed to establish the feasibility and performance capabilities of the next generation nuclear energy systems. GIF has fourteen Members which are signatories of its founding document, the GIF Charter. Among the signatories to the Charter, eleven Members (Australia, Canada, Euratom, France, Japan, the People's Republic of China, the Republic of Korea, the Republic of South Africa, Russian Federation, Switzerland and the United States) have signed or acceded to the Framework Agreement. The goals adopted by GIF provided the basis for identifying and selecting six nuclear energy systems for further development. The selected systems are based on a variety of reactor, energy conversion and fuel cycle technologies. Their designs include thermal and fast neutron spectra cores, closed and open fuel cycles. The reactors range in size from very small to very large. Industrial and societal objectives of Generation IV (8 technology goals) (1) Sustainability	Noted	Georges VAN GOETHEM	Royal Academy of Overseas Sciences of Belgium (ARSOM - KAOW)	Belgium
18609	22	25	22	25	"project by project" -> "project-by-project"	Noted	Thomas Gibon	Luxembourg Institute of Science and Technology (LIST)	France
36739	22	25	22	29	You left out LCOE and other economic arguments here, which would weaken your arguments significantly. It is well known that nuclear power is one of the most expensive electrical powers in terms of LCOE (if the manifold subsidies are accounted for in the same way as in wind and PV).	Noted. A section dedicated to nuclear is 6.4.2.4.	Pietro Altermatt	R&D Center of Trinasolar	Germany
5889	22	25			No mention of nuclear waste issues, proliferation or new plant designs- eg generation IV and smaller scale	Noted. It is in section 6.2.4.2	Ralph Sims	Massey University	New Zealand
15611	22	29	22	43	It should read "Policy initiative to tax carbon and promote low-carbon energy use....." delete tax after carbon ....around half of this in the form of electricity (89.3 Terrawatt-hours (TWh)). It can be written this way "....around half of this in the form of electricity; 89.3Terrawatt-hours (TWh)".	Noted. A section dedicated to CCS is 6.4.2.5	Joseph Essandoh-Yeddu	Energy Commission	Ghana
34109	22	34	22	35	This wording is controversial. It would be fairer to say that projections are over-estimated and not consistent with the current trend.	Noted	Antoine BONDUELLE	Climate Action Network France	France
35429	22	34	22	35	This wording is controversial. It would be fairer to say that projections are over-estimated and not consistent with the current trend.	Noted.	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France
34383	22	36	22	38	The first phrases of this paragraph concern CCS not CCU, thus CCUS should be replaced by CCS. There (line 38) a sentence about CCU should be added, e.g. " The CO2 capture and use (CCU) to create valuable products might lower the net costs of reducing emissions or removing carbon dioxide from the atmosphere.Taking the main production pathways (e-fuel, building material, chemicals, biochar, microalgaes) up to 8 Gt of CO2 per year could be utilised (REFERNCE: Hepburn et al., Nature | Vol 575 | 7 November 2019)	Partially accepted. CCUS is now replaced with CCS and this section focuses on recent trends. A dedicated discussion on CCUS is in section 6.4.2.5	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
20347	22	36	22	41	CCUS' is a highly misleading wording and requires major revision. Correct is to separate 'CCU' and 'CCS'. These two aspects are COMPLETELY different, since CCU describes the reuse of CO2 (for point sources), while even CO2 direct air capture is included as DACCU. CCU of renewables sources (e.g. pulp & paper industry, or renewable energy based DAC) is part of a zero GHG emission system and also required earlier throughout the transition. CCS is used later, in particular for negative CO2 emissions. Literature for a clear separation are 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). This entire chapter requires major revision in separation of CCUS. Please also notice that many use Power-to-X (PtX) synonoumus to CCU (see also Breyer et al. for that), this should be better reflected in the entire chapter.	Partially accepted. CCUS is now replaced with CCS and this section focuses on recent trends. A dedicated discussion on CCUS is in section 6.4.2.5	Christian Breyer	LUT University	Finland
27915	22	38	22	38	The IPCC states, "New (CCSUS) facilities may capture up to 13 Mt CO2 annually." This claim is contradicted by data from, for example, the Petra Nova coal-CCS facility in Texas. The data indicate that, before even accounting for what happens to the captured CO2, only 11-20%, not 85-90%, of CO2 is captured. 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. This contention is supported further by Sekera, J., and A. Lichtenberger, The carbon capture conundrum: Public need versus private gain, A public policy perspective on carbon dioxide capture, 2020, https://drive.google.com/file/d/1K-BIULOUtfSs5LVCS9ONaDzq7jeFmO-b/view. Further, most CO2 captured today is used for enhanced oil recovery, and there is zero proof any CO2 is actually captured, as half the captured CO2 is lost or bound in the oil (which is eventually burned back to the air) during the recovery process, and there is no proof the rest of the CO2 stays in the ground. Please clarify the text to state that too little is known about whether CCUS even reduces CO2 marginally or whether CO2 stays in the ground when it is used for processes such as enhanced oil recovery to suggest it is a potential solution to global warming.	Taken into account. Data revised based on 2019 report from Global CCS Institute. A dedicated discussion on CCUS is in section 6.4.2.6	Mark Jacobson	Stanford University	United States of America
11351	22	39	22	39	It is better to replace 'To promote low carbon energy use' by 'To promote low carbon energy production'	Accepted	PINAKI SARKAR	CSIR-CENTRAL INSTITUTE OF MINING AND FUEL RESEARCH	India
18611	22	39	22	39	"tax carbon tax" -> either "tax carbon" or "carbon tax"	Corrected	Thomas Gibon	Luxembourg Institute of Science and Technology (LIST)	France
38069	22	39			"Tax" has been written twice: delete the second one	Corrected	Craig Jamieson	Straw Innovations Ltd	Philippines
44381	22	39			typo: "to tax carbon tax" should be e.g. "to tax carbon emissions"	Corrected	Pietro Guarato	University of Lausanne	Switzerland
31417	22	42	22	42	Please transfer PJ in Wh!	Accepted	Patrick Jochem	German Aerospace Center (DLR)	Germany
33261	22	42	22	48	Geothermal: under this item 2 very different technologies are represented. The low temperature geothermal energy, with heat pumps is a technology which brings buiding heating toward electrification, thus it is important in terms of strategy.	Noted. A dedicated discussion on geothermal is in section 6.4.2.8	Marc Darras	Association 4D	France
16261	22	42	23	2	In the text giving background information related to geothermal power, consider revising the text in a major way to include the potential of enhanced geothermal energy, which is currently not treated in the analysis. Notably, drilling infrastructure from the oil/gas sector could be used to develop wells and reservoirs for enhanced geothermal energy. Briefly, enhanced geothermal does not require endemic water resources nor is it restricted to tectonically active regions. Instead drilling is done with deep wells and heat extraction for electricity generation uses a closed-loop system typically with either water or CO2 as the heat transfer fluid. The development of appropriate drilling technology to develop enhanced geothermal wells and reservoirs is a current area of investment by, e.g. oil companies in Texas, and may provide an avenue for rapid energy transition. Oil and gas companies would have an incentive to transition to being primarily geothermal energy companies in some scenarios. Moreover, most of the cost in geothermal is upfront, thereby providing an opportunity for developed countries to fund transitions elsewhere if they wish. Current issues with enhanced geothermal include poor siting (on existing faults) and drilling choices where development has resulted in large induced earthquakes, and high costs associated with rock types that are not as porous as the oil/gas industry typically drills in.	Noted. A dedicated discussion on geothermal is in section 6.4.2.8	Daniel Helman	College of Micronesia-FSM	Micronesia, Federated States of
10087	22	44			large scale developments	Noted	Maria E. Mondejar	Technical University of Denmark	Sweden
27391	22	46	22	46	An important referenc work is the SRCCL, which is also discussing bioenergy, the text should be better aligned.	Taken into account during text revision	Karlheinz Erb	Institute of Social Ecology, Univ. of Natural Resources and Life Sciences Vienna	Austria

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
1529	23	0	23	0	Comment on pages 23, section 6.3.7 and 56, section 6.4.3.6: Illustrative for commercial activities that can help to drive down the costs of energy storage in batteries, are the Gigafactories being built (Tesla for example). IEA report: https://www.iea.org/reports/global-ev-outlook-2018. News items: https://www.iea.org/reports/global-ev-outlook-2018; https://www.mckinsey.com/industries/oil-and-gas/our-insights/recharging-economies-the-ev-battery-manufacturing-outlook-for-europe.	Noted	Paul Vethman	PBL Netherlands Environmental Assessment Agency	Netherlands
25839	23	1	23	30	Similar to transportation, I don't know if this is necessarily the right place to put this, but it needs to be mentioned somewhere that the carbon neutrality of this technology is entirely dependent on what you're charging from. If peak shaving battery technologies are charged from coal, that can be worse than the gas that they are likely replacing.	Noted. A dedicated section for energy storage is 6.4.3	Jonathan Buonocore	Harvard University	United States of America
28867	23	1	23	39	figure is not clear, and there is no clear explanation about the relation of the paragraph with the figure (the paragaraph doesn't mention the figure).	Figure removed during revision. A dedicated section for energy storage is 6.4.3	Marissa Malahayati	National Institute for Environmental Studies	Japan
6351	23	3	24	2	The section 'A rapid evolution in energy storage' implicitly conveys the message that energy storage equates to electricity storage. However, there are prominent other forms of storage that are also relevant and increasing. In particular, thermal energy storage should be considered in this section including some costs estimations	This section is to discuss the latest trends in electricity storage that affect renewable integration and EV deployment. More detailed discussion on storage is in section 6.4.3	Sciacovelli Adriano	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
43557	23	3	24	2	What this description lacks, is putting the combined energy storage (current and projected) capacity into context - how does the total capacity compare to the global energy production. This is extremely important, because it will clearly show, that despite all the rapid progress and growth of this business sector, its significance is and remain very limited.	Noted. This section was rewritten to focus on recent trends in electricity storage. A dedicated section on energy storage is 6.4.3	Adam Blazowski	FOTA4Climate.org	Poland
44769	23	3	24	2	The section discusses projections from an economical and technical view, but it could also be relevant to discuss resource limitations and related environmental effects as the needed amount of storage is substantial.	Noted. This section was rewritten to focus on recent trends in electricity storage. A dedicated section on energy storage is 6.4.3	Daniel Westlén	Liberal party Swedish parliament	Sweden
45061	23	3	24	2	I think that 'super interconnections' should be at least mnentioned as they will reduce the need of storage, if electricity can be easily transferred beteen regions	Noted. This section was rewritten to focus on recent trends in electricity storage. A dedicated section on energy storage is 6.4.3	Ziv Hameiri	The University of New South Wales	Australia
9529	23	3			Section 6.3.7 does not discuss possible spin-off (and possibly competing claims on resources and production capacity) from automotive battery development	Noted. This section was rewritten to focus on recent trends in electricity storage. A dedicated section on energy storage is 6.4.3	Tom Kram	PBL (Fellow)	Netherlands
16263	23	3			In Section 6.3.7 A rapid evolution in energy storage, consider adding a brief treatment of the two types of pumped hydro, i.e. conventional and underground, for the sake of clarity and as a service to readers.	Noted. This section was rewritten to touch upon the recent trends. A dedicated discussion on pumped storage can be found in section 6.4.3	Daniel Helman	College of Micronesia-FSM	Micronesia, Federated States of
6353	23	4	23	4	It is suggested to differentiate between electrical storage and other forms of energy storage. Battery, pumped hydro, hydrogen and compressed air are forms of electrical storage.	Text revised. This section covers recent trends in electricity storage. A dedicated section for energy storage is 6.4.3	Sciacovelli Adriano	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
13691	23	4	23	4	This line should include thermal storage, both domestic (e.g. https://www.sunamp.com/) and inter-seasonal thermal stores (as used as part of district heating systems in Denmark etc - see: https://commonweal.scot/policy-library/just-warmth)	Text revised. This section covers recent trends in electricity storage. A dedicated section for energy storage is 6.4.3	Keith Baker	Built Environment Asset Management (BEAM) Centre, Glasgow Caledonian University	United Kingdom (of Great Britain and Northern Ireland)
10089	23	4			includes battery storage, thermal storage, pumped hydro... (thermal storage is largely used in CSP, and it is being more and more considered for district heating systems and industry)	Noted. This section was rewritten to focus on recent trends in electricity storage. A dedicated section on energy storage is 6.4.3	Maria E. Mondejar	Technical University of Denmark	Sweden
26587	23	4			...and thermal storage in connection with district heating.	Noted. This section was rewritten to focus on recent trends in electricity storage. A dedicated section on energy storage is 6.4.3	Peter North	Calorem Ltd, Imperial College (part-time PhD student)	United Kingdom (of Great Britain and Northern Ireland)
9615	23	6	23	7	I had trouble understanding what the sentence "As renewable penetration...." was trying to say.	The text was dropped during revision	David Sholl	Georgia Institute of Technology	United States of America
39659	23	6	23	8	Clarify wether this is actually "storage requirement" as amount of energy stored or available capacity to store energy.Cebulla et al. quite clearly consider required storage capatity, making the unit of TWh/yr incorrect.	Taken into account. Text revised to refer to storage as available capacity to store energy. Units revised accordingly.	Simon Davidsson Kurland	Chalmers University of Technology	Sweden

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
42353	23	6	23	9	There are other studies that examined the link between storage need and penetration. These studies showed that a penetration of up to 90% is possible with storage size lower than the local daily average demand[1-6]. To go beyond 90% VRE, seasonal storage will be mandatory. In that case, the storage size will grow up to 30 daily average demand depending on resource, location and the target penetration level[1-2]. But most locations around the globe has other resources to complement VRE, thus the storage need will most likely remain less than 1 daily average demand for such locations. Note that to increase storage use (at the same time storage size) to reach to same penetration allowing an optimal curtailment during system design will be mandatory. 1.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 2.Solomon AA, Bogdanov D, Breyer C (2019) Curtailment-storage-penetration nexus in energy transition. Applied Energy 235:1351–1368 3.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. 4.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 5.Solomon AA, Faiman D, Meron G (2011) Appropriate storage for high-penetration grid-connected photovoltaic plants. Energy Policy 40:335–344. 6.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.	Text revised. This section covers recent trends in electricity storage. A dedicated section for energy storage is 6.4.3	Solomon Asfaw	LUT University	Finland
35599	23	6			As renewable penetration increases above 80%' - of what, peak power, electricity supply, final energy, primary? What does this refer to, modelling, scenario work and over what geography and with what other assumptions?	Noted. This section was rewritten to focus on recent trends in electricity storage. A dedicated section on energy storage is 6.4.3	Robert Gross	Imperial College and UKERC	United Kingdom (of Great Britain and Northern Ireland)
25053	23	10	23	10	Delete "of which"	Taken into account during text revision.	Eleni Kaditi	Organization of the Petroleum Exporting Countries (OPEC)	Austria
31419	23	10	23	10	Please include “mainly” in front of “limited”	Taken into account during text revision.	Patrick Jochem	German Aerospace Center (DLR)	Germany
34209	23	10	23	10	"considerably high" could be improved and updated	Taken into account during text revision.	Antoine BONDUELLE	Climate Action Network France	France
18683	23	10	23	11	Currently, the costs of electrochemical storage are considerably high, because of which their use is limited to off-grid applications' - the word 'currently' should be avoided in a fast moving field such as storage. Electrochemical storage is definitely not just limited to off-grid applications in 2020 (e.g. behind the meter energy storage)	Taken into account during text revision.	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
20349	23	10	23	21	existing storage technology linked to learning curves, as already mentioned in this section is well able to run a 100% renewable energy system, as highlighted by Bogdanov et al. (https://www.nature.com/articles/s41467-019-08855-1) in full hourly resolution for the world structured in 145 regions as energy transition analyses - as a least cost case, lower in cost than today. This important information should be added to deliver a holistic view.	Noted. A dedicated section for energy storage is 6.4.3	Christian Breyer	LUT University	Finland
34211	23	10	23	21	this part is important but could be more readable, maybe through a graph	Taken into account during text revision.	Antoine BONDUELLE	Climate Action Network France	France
24323	23	11	23	11	The short sentence « with added investments » is extremmely vague as those investiments are not known and may be very high. It looks like a bet.	Taken into account during text revision.	Alan BURLOT	Commissariat à l'énergie atomique et aux énergies alternatives	France
31675	23	11	23	11	The short sentence « with added investments » is extremely vague as those investments are not known and may be very high. It looks like a bet.	This text was revised during SOD	Alan BURLOT	Commissariat à l'énergie atomique et aux énergies alternatives	France
45057	23	12	23	12	I think, pumped-hydro should be included here	Taken into account during text revision.	Ziv Hameiri	The University of New South Wales	Australia
42355	23	14	23	15	The corresponding statement does not read well, something is missing in the portion of this statement after the “and”.	Taken into account during text revision.	Solomon Asfaw	LUT University	Finland
6355	23	15	23	15	what $175/kWh refers to? Is it for mobile applications? Please clarify	This data was dropped during text revision. A dedicated section on energy storage is 6.4.3	Sciacovelli Adriano	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
14463	23	15	23	15	"[O]nce 1 TWh capacity is installed"; TWh is not a unit of capacity, but generation. So it should be "1 TW of capacity" (more likely) or "1 TWh of generation" (which would be strange).	This data was dropped during text revision. A dedicated section on energy storage is 6.4.3	Jean-Sébastien Landry	Environment and Climate Change Canada	Canada

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9995	23	16	23	17	… by 2040, or earlier depending on market growth (based on Schmidt et al., 2017)	This data was dropped during text revision. A dedicated section on energy storage is 6.4.3	Haris Doukas	School of Electrical and Computer Engineering, National Technical University of Athens	Greece
15053	23	18	23	20	the pumped hydro and compressed air storage are not real long term possibilities. The hydrogen and synthetic methane would be better for	Noted. This text was dropped during revision. A dedicated section on energy storage is 6.4.3	Béla Munkácsy	ELTE University	Hungary
18685	23	18	23	20	Thus, lithium-ion and lead-acid batteries, which have the highest installed levels currently, are not suitable for seasonal storage and long-duration discharge which may be better served by pumped hydro or compressed air storage' consider a change to: 'Thus, lithium-ion and lead-acid batteries, which have the highest installed levels currently, are not suitable for seasonal storage and long-duration discharge which are be better served by low-carbon fuels' pumped hydro is not typically used for seasonal storage, Norway has lots of hydro which has seasonal stores in catchment areas - and uses pumps - but this is not typical of pumped hydro.	Noted. This text was dropped during revision. A dedicated section on energy storage is 6.4.3	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
39171	23	18	23	20	Neither pumped hydro nor compressed air are really suitable for seasonal storage. Better is hydrogen storage, see (Schmidt et al 2019 https://doi.org/10.1016/J.JOULE.2018.12.008 quoted in same paragraph)	Noted. This text was dropped during revision. A dedicated section on energy storage is 6.4.3	Tom Brown	Karlsruhe Institute of Technology	Germany
38003	23	19	23	20	Please reconsider, neither pumped storage nor compressed air energy storage can provide seasonal storage. However, storage hydropower can provide this (it is done today in countries like Canada, USA, Noraway, Tadjikistan, Brazil, etc).	Noted. This text was dropped during revision. A dedicated section on energy storage is 6.4.3	Atle Harby	SINTEF Energy Research	Norway
37987	23	20	23	20	Include "storage hydropower" in the sentence	Noted. This text was dropped during revision. A dedicated section on energy storage is 6.4.3	Atle Harby	SINTEF Energy Research	Norway
37989	23	20	23	20	It is a bit strange to include compressed air storage (CAES) the same way as pumped hydro. There are only a few CAES built in the world (until recently only two from the 1970's, one in Germany and one in the US), and when they generate power they are used to drive gas turbines. It is not really low-carbon	Noted. This text was dropped during revision. A dedicated section on energy storage is 6.4.3	Atle Harby	SINTEF Energy Research	Norway
45059	23	20	23	20	Regarding pumped hydro, worth to ref to work from ANU (Australia) regarding pumped hyro storage (see IEEE JPV, 9, pp 1828-1833, 2019 and more)	Noted. This text was dropped during revision. A dedicated section on energy storage is 6.4.3	Ziv Hameiri	The University of New South Wales	Australia
26111	23	20	23	21	The quoted cost for storage ($250/MWh@2050) is outdated. In the already referred Schmidt 2019 paper (https://www.sciencedirect.com/science/article/pii/S254243511830583X), it states the cost of most cost-efficient technologies at 2015 (not 2050) is already $250/MWh, and anticipated to reduce to $150/MWh in 2050.	Noted. This data was dropped during revision. A dedicated section on energy storage is 6.4.3	Keiichiro Sakurai	National Institute of Advanced Industrial Science and Technology	Japan
31421	23	22	23	39	You may also argue that these storages can be applied on decentral level as well and there emerge many interesting business cases.	Noted. Energy storage covered in detail in section 6.4.3	Patrick Jochem	German Aerospace Center (DLR)	Germany
42357	23	25			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. Please read at least [3]. 1.Solomon A.A. Large scale photovoltaics and the future energy system requirement. AIMS Energy, 2019, 7(5):600–618 2.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 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 (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. 5.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 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, 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.	Noted. This section was rewritten to focus on recent trends in electricity storage. A dedicated section on energy storage is 6.4.3	Solomon Asfaw	LUT University	Finland
12891	23	30	23	31	Cost estimates of end of life management may be brought out and may add at the end of line 31 "Also the energy density being very high at the storage location, may require additional security measures, which inturn would add to the cost."	Noted. This data was dropped during revision. A dedicated section on energy storage is 6.4.3	ASHOK NEMA	Nuclear Power Corporation of India Limited	India
14465	23	31	23	31	Should add a sentence to note that storage technologies can also increase GHG emissions (e.g. Hittinger and Azevedo (2017), Environ. Sci. Tech. 51, 12988-12997).	Noted. GHG emissions from energy storage covered in section 6.4.3	Jean-Sébastien Landry	Environment and Climate Change Canada	Canada

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
34815	23	31	23	32	Figure 6.11 Projections for future levelized costs of storage for various technologies requires editting. The wordings looks poor.	Noted. This figure was dropped during revision	Onema Adojoh	Missouri University of Science and Technology, Rolla, USA	United States of America
38027	23	31	23	33	it is very strange to see a comparision of pumped storage, flywheels and batteries. They deliver storage at very different time intervals and other metrics should be used to compare than LCOE. They are all complementary	Noted. This text was rewritten with revisions. A dedicated section on energy storage is 6.4.3	Atle Harby	SINTEF Energy Research	Norway
43681	23	33			Fig. 6.11 appears quite pessimistic on Li-Ion. Tesla is 2019 down to 158$/kwH, about a factor 2 below what the graph suggests for 2020. https://news.yahoo.com/teslas-battery-costs-dropping-quickly-115429951.html?guccounter=1&guce_referrer=aHR0cHM6Ly9kdWNrZHVja2dvLmNvbS8_dD1mZmFiJnE9dGVzbGErYmF0dGVyeStjb3N0cyZhdGI9djE5OS0xJmlhcj1uZXdzJmlhPW5ld3MmaWFpPWh0dHBzJTNBJTJGJTJGbmV3cy55YWhvby5jb20lMkZ0ZXNsYXMtYmF0dGVyeS1jb3N0cy1kcm9wcGluZy1xdWlja2x5LTExNTQyOTk1MS5odG1sJnBuPTE&guce_referrer_sig=AQAAAKOCWNA8sLOpfBqiVl1j2myk7t0o-6XWocD-8ccAWSY0zkmZCRp1QvpQuewYHSN_7mLJ6NqTVl3r153-La_FgOfyXn_Jy7WFCWpWHD6f4euN1wOMqBD0-TUZrTQCWBzGShIB1LPzgwkNFOh_m9hZJmvr6VYoRRlgGfRrxHvFzaoE	Noted. This figure was dropped during revision. A dedicated section on energy storage is 6.4.3	Felix Creutzig	MCC Berlin	Germany
20351	23	36	23	38	this statement is true, however CAES potential is very high and rather well distributed around the world, as presented by Aghahosseini and Breyer (https://www.sciencedirect.com/science/article/pii/S0196890418305351)	Noted. This text was rewritten with revisions. A dedicated section on energy storage is 6.4.3	Christian Breyer	LUT University	Finland
38029	23	36	23	38	I don't agree that chellenges are more "diverse" for pumped hydro and CAES than for batteries. I think this phrase could be written more objective by writing that challenges are different for different types of storage. They can be related to costs, location, use of minerals and other material, environmental impacts, lifecycle greenhouse gas emissions, safety, etc.	Noted. This text was rewritten with revisions. A dedicated section on energy storage is 6.4.3	Atle Harby	SINTEF Energy Research	Norway
14275	23	38	23	38	Addition: "One should also not forget the possibilities that power-to-gas and power-to-liquid solutions provide by storing energy in a gaseous and liquid form, which is easier to handle and transport than electrons, and can compensate for seasonal supply fluctuations and contribute to enhancing energy security (SDSN & FEEM 2019, https://roadmap2050.report/; Ampelli et al. 2015, http://dx.doi.org/10.1098/rsta.2014.0177; Bogdanov et al. 2019, https://doi.org/10.1038/s41467-019-08855-1)"	Noted. A dedicated section on energy storage is 6.4.3	Anastasios Perimenis	CO2 Value Europe (Association) - CCU Offiver	Belgium
42359	23	38	24	2	Storage optimal use also depends on its design, curtailment and system dispatch[5]. Please see [2,4]. This have significant impact on the system. 1.Solomon AA, Bogdanov D, Breyer C (2019) Curtailment-storage-penetration nexus in energy transition. Applied Energy 235:1351–1368 2.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. 3.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 4.Solomon AA, Faiman D, Meron G (2011) Appropriate storage for high-penetration grid-connected photovoltaic plants. Energy Policy 40:335–344. 5.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.	Noted. This section was rewritten to focus on recent trends in electricity storage. A dedicated section on energy storage is 6.4.3	Solomon Asfaw	LUT University	Finland
39887	23		23		Section 6.3.7 : There is no mention of thermal energy storage which plays a vital role in many energy systems including solar thermal, although included in section 6.4.3.	Noted. A dedicated section on energy storage is 6.4.3	SANJEEV JAIN	IIT DELHI	India
33275	23				Chapter 6.2.8 on policy instrument, taxation and subsidies should reference the OECD studies on this matter.	Noted	Marc Darras	Association 4D	France
1533	24	0	24	0	Comment on section 6.3.8, and related to section 6.7.5 on page 117: In this section a concluding remark, preferably based on scientific literature (meta study?), can be made that mandatory policies (command and control, such as building codes, norms for appliances, obligations to undertake cost effective saving measures, etc.) are probably the most effective policies throughout history, as they have reached the highest energy savings and/or GHG reductions.	Noted. This section focuses on recent trends. A dedicated discussion on policy is in Chapter 13	Paul Vethman	PBL Netherlands Environmental Assessment Agency	Netherlands
33265	24	1	24	3	regulatory instrument and fiscal instrument do not correspond generaly to the same market. For instance in a disperse market such as insulation for energy efficiency, norms and regulation will impose standards as they are seen economically feasible. The flexibility of tax is adequate on a more standardised set of items (for instance the various fuels). One important question which is not often considered is the use of the revenue, either in the general budget or dedicated to specific CC purpose. If the latter is often better in term of acceptability it is not necessarily the best use. Therefore, this § should better consider the case of different instruments.	Noted	Marc Darras	Association 4D	France

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
43559	24	3	25	42	This chapter completely omits the issue of energy market organisation. In fact this is one of the most critical aspects which will decide how do we tackle climate change on global scale. Market-based systems with limited role of governments create a natural preference to short-lifetime technologies with short payback costs. But there is still a huge group of countries, which have not adopted this model, which see the energy system as one of the key obligations of the state, and where the state controls fully or partially much more processes, than it does in e.g. Western Europe. Those countries are much more willing to invest also in long-term technologies, such as nuclear and hydro power. Also the role of central planning in the context of climate change should not be forgotten. As it is, this sections seems to be written completely from the Western perspective of market-based energy systems, which is a distortion of reality, and also completely discards the discussion of the issue, whether this is the right approach in the first place.	Taken into account. The "government provision of public goods" and the "regulatory instruments" category in table 6.3 capture the recent trends in public provision of low-carbon infrastructure. THis is also explained towards the end of the section in SOD. A dedicated discussion on this issue is left to Chapter 13	Adam Blazowski	FOTA4Climate.org	Poland
17705	24	3	25	43	It is inevitably tricky to condense polcy/trends into a short space. Some liaison with Ch.13 / cross referencing and its classificaiton approach might be useful.	Taken into account and changes made to the table with reference to Ch. 13	Michael Grubb	UCL - Institute of Sustainable Resources	United Kingdom (of Great Britain and Northern Ireland)
43041	24	3	27	44	The policy section should endevaour to use the policy assessment criteria as discussed in Ch13 as far as possible, to standardize the terminology of assessment. Some specific instances are discussed below. For instance, on Pg 24 (line 13) and Pg 25 (lines 1 to 3), the assessment criteria "feasibility" could be explicitly used. Feasibility is defined in table 13.3 as "the ability of governments to implement a policy instrument in practice; may include technical, social, institutional, political, economic or social constraints".	Taken into account and changes made to the table and the section in consultation with Ch. 13	Parth Bhatia	Centre for Policy Research, New Delhi	India
16265	24	4	24	9	In the first paragraph of this section on energy policy, consider adding a sentence describing governmental choice and its effect on military emissions, for clarity.	Rejected. This is out of scope of this section. More discussion on policy in Chapter 13	Daniel Helman	College of Micronesia-FSM	Micronesia, Federated States of
4451	24	5	24	5	Coupling policies on renewable energy and energy efficiency domains for the heat sector and combining them with climate policies will be required to move forward decarbonisation and sector integration	Noted.	Leonardo Barreto	Austrian Energy Agency	Austria
43725	24	5	24	5	command and control'? What does this mean - the phrase has strong politicised connotations - it is generally used pejoratively in policy contexts where there is a preference for 'market based' policies. More importantly, but it doesn't mean anything specific and should be replaced with more exact wording for what is being referred to.	Accepted. Replaced with specific standards	Kirsty Hamilton	Chatham House (Associate Fellow, unpaid)	United Kingdom (of Great Britain and Northern Ireland)
33267	24	6	24	7	FIT is covering different items. In the early stage it covers the extra cost of the new technology, and correspond to the social choice of it. In a more mature stage, if there is no or little carbon taxation, it represents the positive externality of this technology. However, in the case of a strong carbon tax system this is not needed because the negative externalities of carbon emission is taken into account compartively. Therefore, I understand that ypu present here observations. However, it might be helpful to have a more complete discussion of taxation, incentives and regulation since they should be useful tool for implementing scenarios.	Noted. This section briefly discusses the recent trends in policy but more detailed discussion on taxation, regulation and incentives can be found in Chapter 13	Marc Darras	Association 4D	France
43727	24	6	24	8	To make the list of 'policies and institutional mechanisms' more comprehensive add planning and permitting regimes. There is one reference to 'Urban planning programmes' in the table below but planning permission more generally is a critical issue for developers and investors.	Noted.The policy category "government provision of public goods" covers "urabn planning programmes". THe said policy category is mentioned in the text	Kirsty Hamilton	Chatham House (Associate Fellow, unpaid)	United Kingdom (of Great Britain and Northern Ireland)
33269	24	6	24	9	Using FIT or ETS / Auction does not address the same market. Because of costs of transaction, ETS/Auction concerned only large enough emissions/reduction of emissions, while FIT can be easily adaptated to small input. FIT and Auction give the same guarantee to the investor. ETS, which address primarly emission reduction, is not a dirct tool for REN.Furthermore, the question is essentially on allocation.	Noted	Marc Darras	Association 4D	France
15525	24	10	25	42	The standard typology of policies in Table 6.3 is helpful, though it would be helpful if it included not just policies to include low-carbon technology options, but also those that specifically move away from fossil fuels. See e.g. following two sources for ideas on how to supplement the typology / table shown: Lazarus, M. & van Asselt, H. Fossil fuel supply and climate policy: exploring the road less taken. Climatic Change 150, 1–13 (2018). Green, F. & Denniss, R. Cutting with both arms of the scissors: the economic and political case for restrictive supply-side climate policies. Climatic Change 150, 73–87 (2018)	Noted. The table was updated in SOD to be consistent with policy categories and instruments defined in CH. 13 which conducts a detailed synthesis of the policy issues	Peter Erickson	Stockholm Environment Institute	United States of America
25055	24	14	24	14	Delete "If designed well, not too regressive", as such expressions are too general and not based on national circumstances	Accepted. Text revised to bring in more clarity	Eleni Kaditi	Organization of the Petroleum Exporting Countries (OPEC)	Austria
16959	24	14	24	15	"If designed well, redistributive effects are not too regressive" , this sentense, somehow, is hard to understand. A more readable sentense is suggested here.	Accepted. Text revised to bring in more clarity	Qing YANG	Harvard University	China
34213	24	16	24	16	In the figure line 1, maybe add "industry-wide agreements"	Taken into account. The policy categories and instruments in the table are now revised to make them cosistent with the definitions in CHapter 13 which deals with policy in detail	Antoine BONDUELLE	Climate Action Network France	France

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
10897	24	16	24	17	Under renewable energy in the table, Renewable energy auctions should be added as a major new type of policy inteervention. Oscar Fitch-Roy and David Benson have produced some analysis of this in a European context. Mention could also be made of contracts ofr difference.	Taken into account. The policy categories and instruments in the table are now revised to make them cosistent with the definitions in CHapter 13 which deals with policy in detail	Ian Bailey	University of Plymouth	United Kingdom (of Great Britain and Northern Ireland)
14467	24	16	24	17	In the #1 category, could add the coal phase-out of electricity power plants in Canada.	Accepted	Jean-Sébastien Landry	Environment and Climate Change Canada	Canada
33271	24	16	24	17	Flexible economic instrument have been favoured by economists. However, if this may be true on the long term certainly for large investment, it may not be be an important element at the decision stage: for instance, malus/bonus system for cars have had a very important influence for subsequent emission which are not reflected in the price of the car; similarly, regulation on insulation which in economic terms has a cost help implement such policy. This is mainly due to the fact that consummer very rarely consider actual value along the life of the product, or have a very short time perspective which gives weigh to the direct spending. This pargraph should be modulated.	Noted. Lines 16 to 17 contain the table which contains the table on "recent trends in climate related energy policies". Here we only tabulate the policy categories and instruments with some examples in recent years. Further discussion on suitability of instruments could be found in Chapter 13	Marc Darras	Association 4D	France
43729	24	16	24	17	There is no reference here to renewable energy auctions. I suggest a reference from REN21 Global Status Report 2019: it states on page 21 under the 'Power' subheading that "auctions were held in at least 48 countries (up from 29 the year before)". The GSR is available from: https://www.ren21.net/reports/global-status-report/. I note that page 37 line 25 refers to 'the current trend towards auctions'.	Taken into account. renewable energy auctions were included in examples of recent policies	Kirsty Hamilton	Chatham House (Associate Fellow, unpaid)	United Kingdom (of Great Britain and Northern Ireland)
45155	24	16	24	17	The example of the policy instrument "technology phase-out mandates" can also include the banning of gas heating boilers, e.g. Netherlands, including switch to geothermal district heating and waste based district heating.	Accepted	Siir Kilkis	The Scientific and Technological Research Council of Turkey	Turkey
30937	24	16	24	18	figure 6.3 I would add carbon taxes	Accepted and added	Pietro Bartocci	University of Perugia	Italy
43039	24	16	24	18	This table would benefit from harmonizing the policy categories with the taxonomy proposed by the policy chapter (Ch 13). The current policy categories broadly map onto the Ch13 taxonomy, but there are other classes of instruments in Ch13 which have not been addressed in Ch6 (eg. voluntary agreements, divestment). If the recent global trends include increasing popularity for some of these categories, then they should be included to make the table more comprehensive.	Taken into account and changes made to the table	Parth Bhatia	Centre for Policy Research, New Delhi	India
43043	24	19	24	21	The taxonomy doesn't map onto the taxonomy used in ch13. For instance, investment in public goods is characterized as an economic instrument here whereas "government provision" of goods/services is categorized under "other policies" in ch 13.	Taken into account and changes made to the table	Parth Bhatia	Centre for Policy Research, New Delhi	India
33273	24	34	24	36	Carbon tax and border tax adjusment. This argument is to be considered beside the other factor of competitiveness which may a much bigger effect (cost of labour, technicity). A Border tax adjustment can only be considered on feedstock and upstream materials, because of the complexity of tracing every parts in a final product. Furthermore, the question of international carbon tax is complex and its value may depend of the stage of the economy. In the Paris Agreement negociation it has been carefussly set aside.	Noted	Marc Darras	Association 4D	France
44311	24		24		Under Flexible regulation please add Energy Companies Obligations in the EU MSs to save energy in end-users, see for more information Fawcett, T., Rosenow, J. & Bertoldi, P. Energy efficiency obligation schemes: their future in the EU. Energy Efficiency 12, 57–71 (2019). https://doi.org/10.1007/s12053-018-9657-1	Accepted	BERTOLDI PAOLO	European Commission	Italy
16667	24				Table 6-3. row 1. Germany provides a counter example of a technology phase out mandate (nuclear) which does not result in a better carbon balance.	Noted	Jean Louis Bobin	Sorbonne universités Paris	France
24671	24				In the second line, under Flexible Regulation, it coud be noted that some countries in Latin America plan to use ETS system to limit their emissions. Mexico will start its ETS in 2022. In its adopted Climate Plan, Germany decided to implement an ETS on the non EU-ETS sectors.	Taken into account during table revision	Florent LE STRAT	ELECTRICTE DE FRANCE	France
35597	24				command and control' is not defined or explained and in my view is not an appropriate term to use in this context.	Accepted. This was modified to reflect specific regulatory mechanisms	Robert Gross	Imperial College and UKERC	United Kingdom (of Great Britain and Northern Ireland)
45063	25	6	25	11	FIT is defined twice in just a few lines	Corrected	Ziv Hameiri	The University of New South Wales	Australia
36511	25	16	25	28	In addition to the cost saving by carbon pricing including emission trading for emission reduction, international emission trading can save the cost for achieving NDCs. This kind of analysis should be included. The below is a report which analyses the economic benefit of international emission trading. https://www.ieta.org/resources/International_WG/Article6/CLPC_A6%20report_no%20crops.pdf	This section only deals with trends in carbon pricing from recent years. The projected impacts of carbon pricing on NDCs and related analysis is not the scope of this section. Hence the suggested report cannot be cited here. A detailed discussion on policy is covered in Ch. 13.	Takashi Hongo	Mitsui & Co. Global Strategic Studies Institute	Japan
43045	25	22	25	24	It is worth pointing out that a national ETS is being planned for China (estimated rollout by end of 2020), which will cover the coal fleet of China. It will be one of the largest ETS in the world.	Noted	Parth Bhatia	Centre for Policy Research, New Delhi	India
44313	25	24	25	27	You can cite the IPCC SR 1.5 C and its recommendayin for a carbon prize	Noted	BERTOLDI PAOLO	European Commission	Italy
24673	25	25	25	25	Recent price increase of CO2 price in the EU-ETS is inked to the ETS reform that was decided and implemented from 2019. It appears to be an illustration of the importance of a well design in such kind of mechanisms	Noted	Florent LE STRAT	ELECTRICTE DE FRANCE	France

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
19891	25	36	25	38	”Implicit carbon pricing" take various forms. The sentence starting from "Apart from the regulatory and fiscal measures" should be amended to "Apart from explicit carbon pricing, various implicit carbon pricing mechanisms including regulations, fossil fuel taxes, RE subsidies and removal of fossil fuel subsidies are used by many countries as part of their climate policies"	Accepted	Takahiko Tagami	Institute of Energy Economics, Japan	Japan
25057	25	36	25	42	Delete "Apart from the regulatory and fiscal instruments, … (see box on Energy Subsidies)." as this analysis is not focusing on inefficient subsidies and is not aligned with sustainable development matters	Taken into account during text revision	Eleni Kaditi	Organization of the Petroleum Exporting Countries (OPEC)	Austria
8821	25	44	25	44	Please also see here () for an overview of subsidies, incentivies and other non-market flows in Turkey for both renewable and non-renewable energy technologies in the electricity and heating sectors.	Rejected. Reference is missing.	Saygın Değer	SHURA Energy Transition Center	Turkey
19893	25	44	27	44	While this box article intensively argues about fossil fuel related subsidies, it should also adress renewable energy related subsidies. Massive expansion of RE in global scale is largely predicated to various subsidies such as FIT. Trend of RE subsidies at global level and its correlation with RE penetration should be presented. In Japan, reduction of FIT level has resulted in substantially lower RE introduction, which shows RE boom has been created by policy intervention, not purely by market forces. Such aspects should be presented.	Rejected. Text already mentions subsidies for mititgation and feed-in tariffs in particular.. Issues is more prominently discussed in 6.3.8.	Takahiko Tagami	Institute of Energy Economics, Japan	Japan
34737	25	44	73	9	Consider inclusion of a narrative for "Transfer of Technology" from one country to another that may be lagging in technological advancement.	Rejected. This is not the focus of this box.	Rabiz Foda	Hydro One Networks Inc.	Canada
34743	25	44	73	9	Consider inclusion of a detailed narrative on safety, environmental issues, radiation and electromagnetic fields, health, animal and wildlife, vegetation issues as it relates to power generating plnts, nuclear waste disposal and storage, relicencing of nuclear power reators and plants, human resources development, education and training for the efficient knowledgement management of these plants and systems and design and engineering.	Rejected. This is not the focus of this box.	Rabiz Foda	Hydro One Networks Inc.	Canada
9531	25	44			Box 6.4 seems to miss the extensive work on energy subsidies by the OECD?	Rejected. IEA's and IMF's estimates show full range of estimates, while OECD's inventory approach lies between the two estimates.	Tom Kram	PBL (Fellow)	Netherlands
5213	25	45	25	47	In a broader sense, energy subsidies may also be given to reduce the costs of structural changes, e.g. subsidies for the coaöl industry to phase-out of coal in Germany by 2038.	Rejected. This relates more to general industrial policy and does not fit the applied definition of energy subsidies mentioned in the first sentence.	Andreas Oberheitmann	FOM University of Applied Sciences	Germany
35595	25				Feed in tariffs are not fiscal instruments. As far as I can see, Feed in Tariffs are also not defined or explained.	Accepted. We aligned the wording to the taxonomy of Chapter 13.	Robert Gross	Imperial College and UKERC	United Kingdom (of Great Britain and Northern Ireland)
17707	26	1	27	34	This seems a mature discussion of subsidies. My understanding is that developing countries are more inclined to consumer subsidies whilst developed countries more to production subsidies, but that may be too simplistic or changing. In the context of this or when discussing carbon pricing, it may be worth noting that the share of GDP devoted to energy appears (at least amongst developed countreies including eastern Europe) has tended to a fairly narrow range - countries which subsidise energy to keep it cheap have ended up spending as much due to structural efficeincies, whereas high prices have supported correspondingly higher efficiency, so that the overall cost of energy provision has tended to revert to long-run constancy, despite wide variations in prices between countries. The most recent evidence I know if is in Igor Bashmakov et al, “Minus 1” and energy costs constants: empirical evidence, theory and policy implications, in review with Applied Energy. The underlying analysis is available in a prior working paper: M.Grubb, I.Bashmakov, P.Drummond (June 2017), Minus 1: Empirics, theory and implications of the ‘Bashmakov-Newbery Range of Energy Expenditure’, Final report to INET; https://www.ucl.ac.uk/bartlett/sustainable/publications/2018/apr/exploration-energy-cost-ranges-limits-and-adjustment-process	Rejected. Suggested reference is not published yet.	Michael Grubb	UCL - Institute of Sustainable Resources	United Kingdom (of Great Britain and Northern Ireland)
39331	26	4	26	4	Acclerated depreciation benefit is also applicable for solar PV system in India	Noted. Removed table from the box due to changed focus.	Suvra Majumdar	United Nations Development Programme	India
26589	26	4			Box 6.4, Direct fiancial transfer now applies in England and Wales for loans and grants from government for district heating networksl.	Noted. Removed table from the box due to changed focus.	Peter North	Calorem Ltd, Imperial College (part-time PhD student)	United Kingdom (of Great Britain and Northern Ireland)
3007	26	12	26	14	Also mention the fiscal sustainability related to FIT (e.g., the German experience)	Rejected. FITs are discussed in Section 6.3.8.	Mustafa Babiker	Aramco	Saudi Arabia
23919	26	22	46	22	it would be good to include also the system-freiendly use of biomass in the energy system as aspect (smart bioenergy)	Rejected. Comment does not fit the focus of this box.	Stefan Majer	German Biomass Research Centre - DBFZ	Germany
25059	26		26		Box 6.4, Table 1: Delete "(Oil and electricity in Iran, Saudi Arabia, Egypt, China, India)" as this information is outdated	Noted. Removed table from the box due to changed focus.	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
15707	27	1	27	1	Instead of using the qualitative phrase "A major chunk of energy subsidies is associated with fossil fuels.", would it not be better to use the quantitative estimates in your existing sources, e.g. IEA 2017 & World Bank 2019? Espcially the relative estimated subsidies between fossil fuels and wind and renewables?	Taken into account. Text revised.	CHRISTOPHER BATAILLE	IDDRI.ORG/SIMON FRASER UNVIERSITY	Canada
25061	27	1	27	44	Analysis should be substantially revised to consider inefficient subsidies that encourage wasteful consumption. Research papers such as 'UNEP, OECD and IISD (2019). Measuring fossil fuel subsidies in the context of sustainable development goals, UN Environment, Nairobi, Kenya' should also be considered, as well as long-standing positions and papers developed by the G20 group (e.g. IEA, OECD, OPEC, World Bank. (2010). Analysis of the scope of energy subsidies and suggestions for the G-20 initiative")	Noted. Coordinating with Chapter 13 we have decided to focus on another sustainable development goal (access to modern energy).	Eleni Kaditi	Organization of the Petroleum Exporting Countries (OPEC)	Austria
45429	27	1			It is not clear in what form fossil fuel subsidies are provided in large subsidizers such as China and USA. Providing actual examples will help the reader understand.	Taken into Account. The box has been heavily revised in concert with the policy chapter CLAs.	Girija Parthasarathy	Thermo King	United States of America
31803	27	3	27	4	It is not clear how "actual market price" can be measured to estimate the price gap. Often this leads to methodological infirmities. Should highlight that.	Taken into account. Stressed that it is an estimate.	Ashok Sreenivas	Prayas (Energy Group)	India
18687	27	8	27	8	can vary a lot' to 'can vary by an order of magnitude'	Accepted. Text revised.	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
12893	27	14	27	14	the units for the figures in paranthesis may be mentioned - Millions/Billion ?	Accepted. Text revised.	ASHOK NEMA	Nuclear Power Corporation of India Limited	India
25063	27	14	27	14	Units should be presented	Accepted. Text revised.	Eleni Kaditi	Organization of the Petroleum Exporting Countries (OPEC)	Austria
19613	27	14			"(US$ 649), Russia (US$ 551), European Union (US$ 289) and India (US$ 209)" Unit is in Million?	Taken into Account. The box has been heavily revised in concert with the policy chapter CLAs.	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	China
45431	27	29	27	31	Instead of 'abstract' externalities, can you provide specific examples of 'externalities'?	Accepted. Added examples.	Girija Parthasarathy	Thermo King	United States of America
25065	27	31	27	33	Delete "Similarly, a study of US oil industry … (Erickson et al. 2017)."	Noted. Paragraph deleted in new version.	Eleni Kaditi	Organization of the Petroleum Exporting Countries (OPEC)	Austria
15535	27	33	27	38	The authors Erickson et al and Jewell et al cited here recently had an exchange published in Nature to attempt to reconcile some of the findings listed here. One area of agreement was that IAM models could do a better job of representing investment in fossil fuels and in how a detoriarated investment climate for fossil fuels could increase prospects for low-carbon scenarios. e.g. Erickson, P. et al. Why fossil fuel producer subsidies matter. Nature 578, E1–E4 (2020).	Noted. Paragraph deleted in new version.	Peter Erickson	Stockholm Environment Institute	United States of America
19781	27	45	73	9	There is little to no mentioning of district heating/cooling as a mitigation option anywhere in the chapter. This is however an important measure to increase efficiency over energy systems as shown by e.g. https://doi.org/10.1016/j.energy.2019.04.098 and https://doi.org/10.1016/j.energy.2012.06.011. Please include in this subchapter and in conclusion	Rejected. District heating is addressed in the buildings chapter.	Marie Münster	Technical University of Denmark	Denmark
37397	27	45			Description of mitigation options lacks a comprehensive assessment of technical and economic potential of key technologies, for example solar and wind to achieve large part of emissions reductions needed. For solar there is a statement without substantiation that it could address up to half (see other comment), but for wind it is missing completely. It also misses out on the systemic approach to 1005 RE systems,both grid and distributed systems. Also the role of sector coupling and electrification of end use sectors in turn facilitating RE integration and overall 100% RE systems.	Taken into Account. More informaiton has been added about potential scale. There is an enhanced discussion of 100% renewable systems.	Michiel Schaeffer	Climate Analytics	Netherlands
46689	27	45			Section 6.4 is the only section with a summary. Should not all sections have one?	Taken into account. Summary has been removed.	anna maria sempreviva	Wind Energy Department, Technical University of Denmark, Roskilde	Denmark
26591	27	46	73	9	There is an absence of any review or discussion on the role of district heating and thermal storeage.	Taken into Account. District heating is addressed in the building chapter, but we have a subsection on storage that includes thermal storage, and it has been revised.	Peter North	Calorem Ltd, Imperial College (part-time PhD student)	United Kingdom (of Great Britain and Northern Ireland)
31423	27	47	27	47	You may include after “energy demand “(e.g. transport)”	Taken into Account. Text has been removed for space.	Patrick Jochem	German Aerospace Center (DLR)	Germany
39273	28	16	28	16	Is geophysical really the good term ? The paragraph talks more about georessources than geophysics.	Noted. The feasibility concept has been introduced in SR1.5, we keep the same terminology for consistency reasons	Bruno Gavazzi	UMR7516 Institut de Physique du Globe de Strasbourg (CNRS/Université de Strasbourg	France

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
24631	28	18	28	18	Enabling developing countries	Noted.The enabling conditions are relevant for both developing and developed countries	Sanaz Jafarzadeh	Thermal Power Plants Holding Company	Iran
24633	28	18	28	18	Expreading commercially of affordable and accessable technologies	Noted. This is covered by the bulletstechnology diffution, costs in 2030 and the long term, and energy accessibilityand security	Sanaz Jafarzadeh	Thermal Power Plants Holding Company	Iran
16961	28	18	28	19	The Table 6.4 does not give the all key indictors in assessing the barriers and enablers of implementing options and technologies in low carbon energy systems. For example, GHG emissions is a critical indicator in environmental-ecological but not belong to air pollutions, and externality costs from enivirоment is also an important part in economic indicator calculations.	Noted. GHG emissions is the critical aim of nay mitigation option, so the aim of implementing the options assessed. The feasibility dimensions reflect barriers and enablers of implementing these mitigation options. Assessing the costs of the enviornmental impacts is beyond the scope of AR6	Qing YANG	Harvard University	China
32263	28	18	29	1	Table 6-4 appears to be uncompleted because there is no mention, in the "Economic: What economicconditions can support or inhibit the implementation of the options and technologies?" line of the new paradigm which detremines the value of a given production technology in an energy mix. Clearly, competitiveness is no longer the right criteria. See for instance the works by Hirth (cited 33-5) or by Keppler and Cometto in the OECD/NEA. See also for insstnce the chapters 6.4.6.1. and 6.4.6.2.	Taken into Account. The box and categories have been revised as part of a cross-chapter effort.	Jean-Guy Devezeaux de Lavergne	Commissariat à l'Energie Atomique et aux Energies Alternatives	France
24619	28	18			Enabling developing countries	Noted.The enabling conditions are relevant for both developing and developed countries	Sanaz Jafarzadeh	Thermal Power Plants Holding Company	Iran
24621	28	18			Expreading commercially of affordable and accessable technologies	Noted, this is covered under costs in 2030 and long term	Sanaz Jafarzadeh	Thermal Power Plants Holding Company	Iran
39275	28	19	18	20	Is geophysical really the good term (first entry) ? The entry talks more about georessources than geophysics.	Noted. The feasibility concept has been introduced in SR1.5, we keep the same terminology for consistency reasons	Bruno Gavazzi	UMR7516 Institut de Physique du Globe de Strasbourg (CNRS/Université de Strasbourg	France
23923	28	19	28	19	in the table line "Technological: Can the required technology be upscaled soon?", the know-how/education is also important indicator	Noted. This is indeed one of the factors influencing the likelihood of scale-up, which will be assessed when appropriate in the sectoral chapters	Stefan Majer	German Biomass Research Centre - DBFZ	Germany
34683	28	19	28	20	In the table's se third row: here should be considered as points to scale up the technology the Jevons paradox, the energy trap (Sgouridis Sgouris. 2014, 2, 8. efusing the Energy Trap: The Potential of Energy-Denominated Currencies to Facilitate a Sustainable Energy Transition. Frontiers in Energy Research. 10.3389/fenrg.2014.00008) and the trade-offs (UNEP (2016) Green Energy Choices: The benefits, risks and trade-offs of low-carbon technologies for electricity production. Report of the International Resource Panel. E. G. Hertwich, J. Aloisi de Larderel, A. Arvesen, P. Bayer, J. Bergesen, E. Bouman, T. Gibon, G. Heath, C. Peña, P. Purohit, A. Ramirez, S. Suh, (eds.).). In the fourth row: here should be mentioned the growth needed for the necessary investments in renewables, which will allow to complement the point on investment for renewable energy sources implementation at the necessary rates to face emissions depletion (Abhishek Shivakumar, Audrey Dobbins, Ulrich Fahl, Antriksh Singh, Drivers of renewable energy deployment in the EU: An analysis of past trends and projections, Energy Strategy Reviews, Volume 26, 2019, 100402, ISSN 2211-467X, https://doi.org/10.1016/j.esr.2019.100402.)	Response updated	Jordi Solé-Ollé	Spanish National Research Council (CSIC)	Spain
44601	28	19	28	20	I wonder if there's a term in the literature that's broader than 'acceptability' (here: public and political) since this sounds a little defensive. If you think in terms of (removing) barriers to change, reaching acceptability might be enough, but if you want actors to drive change, it is about more than just 'acceptability'	Noted. Agreed, therefore, likelihood of required behaviour change is added as an assessment criteria too	Oliver Geden	German Institute for International and Security Affairs	Germany
1217	28	19			Include how the indicators are chosen.	Noted, the criteria are based on the feasiblity assessment of SR1.5, and have een extended based on experts inpunt	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
2339	28	20	28	20	In geophysical: Eventually include: recyclability, reuse of materials	response revised and better explained	Dieter Boer	Universitat Rovira i Virgili	Spain
16275	29	1			For Section 6.4.2 Energy Sources and Energy Conversion, consider adding a [Geopolitical] subsection category. This is especially relevant for nuclear power owing to the risk of nuclear arms proliferation embedded in the technology, but also is relevant to wind energy, for example, from the mining of magnet materials (rare earth elements) that produces uranium as a byproduct. A geopolitical analysis would complement the [Institutional] category currently present.	Rejected - outside the scope of analysis and space.	Daniel Helman	College of Micronesia-FSM	Micronesia, Federated States of

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16279	29	1			For Section 6.4.2 Energy Sources and Energy Conversion, consider adding a subsection that explores advances in fusion power to date. Notably, new advances in high-temperature superconductors make parity more likely, since losses associated with the transmission of electricity to establish magnetic containment will be much lower. China is also starting to invest in non-conventional approaches to fusion energy, and many of these non-conventional approaches have not had much research funding yet in the West, so remain a source of future potential.	Not sure where this belongs. GN: we should at least mention it somewhere in the chapter.	Daniel Helman	College of Micronesia-FSM	Micronesia, Federated States of
16963	29	2	29	4	This paragragh is the overview of the sub-parts in 6.4.2, mainly including energy sources (6.4.2.1 solar energy, 6.4.2.2 wind energy, 6.4.2.3 hydroelectric power, 6.4.2.4 nuclear power, 6.4.2.6 bioenergy, 6.4.2.7 fossil energy, 6.4.2.8 Geothermal Energy, 6.4.2.9 Marine Energy, 6.4.2.10 Waste-to-Energy) and energy conversion technologies (6.4.2.5 Carbon Dioxide Capture, Utilization, and Storage). I really do not agree with the structure of 6.4.2. The sub-parts of 6.4.2 is out of order and misleading. It is suggested to divide into two parts, then descript from the aspect of energy sources and energy conversion technologies, respectively.	Rejected. We respectfully disagree. It is often difficult to separate out the sources from the tecnologies. Solar cells are a conversion technology, not a source of energy.	Qing YANG	Harvard University	China
44771	29	5	29	9	I find figure 6.12 useful, but it would also be of relevance to show similar data in delivered amount of electricity.	Accepted - the figure has been replaced by one of the energy geneation instead of installed capacity	Daniel Westlén	Liberal party Swedish parliament	Sweden
27085	29	6	34	18	The structure of the chapter on solar energy does not correpsond to the relevance of the included topics. Many technologies that have great signifcance for installations these years are mentioned very briefly or omitted, whereas other technologies have detailed coverage. Examples are the lack of a discussion of bifacial or tracking technology, whereas CSP is discussed in great detail. To me, the chapter seems to cover state of the art from about 5 years ago. Especially troubling is that recent research on sector coupling and high adoption scenarios of renewables are not included at all. I will follow up with exemplary comments later.	Accepted - strcuture of the text thoroughly revised with emphasis on the most important technologies and developments	Ian Marius Peters	Forschungszentrum Jülcih	Germany
2341	29	8	29	8	green colors on the right bottom are too similar, maybe use other colours.	Accepted. A new figure is now in place.	Dieter Boer	Universitat Rovira i Virgili	Spain
16965	29	8	29	9	Figure 6.12 shows the percentage distribution of main renewable energy, which are almost descripted in sub-parts. In ddition, an important energy source-nuclear energy-is also discussed in 6.4.2. I suggest this figure should be improved not only considering renewable energy but new energy souces.	Rejected - outside the scope of analysis and space.	Qing YANG	Harvard University	China
17061	29	8	29	9	I assume this is installed capacity? This is not very useful, it overvalues the role of solar and wind, with low capacity factors. Suggest to leave out this figure (and - if possible - replace with a picture showing energy generation).	Accepted - the figure has been replaced by one of the energy geneation instead of installed capacity	Kornelis Blok	Delft University of Technology	Netherlands
11533	29	8			AC or DC capacity shares?	Accepted. Revised figure now uses share of electricity (kWh) generated rather than capacity.	Arnulf JÄGER-WALDAU	European Commission, JRC	Italy
23925	29	9	29	9	Clarify in the title, that the figure is about installation for electricity generation only	Accepted - the figure has been replaced by one of the energy geneation instead of installed capacity	Stefan Majer	German Biomass Research Centre - DBFZ	Germany
8877	29	10	34	14	Good agreement with the entire chapter. However, one additional information should be given:Does the costs given in $/kWh or $/Wdc include the back end costs i.e. deconstruction, Recycling or final disposal and storage of solar panels, return to the grass of all the land occupied, including specific access roads, etc?? Litterature is usually silent on these costs, and any information would be useful.	Accepted - new text on recycling and land use added; costs are all updated but do not include end use costs; note that levelized costs include discounting so end of life costs would have small impacts on levelized costs.	Michel SIMON	Vice Président SFENRAL	France
27115	29	10	34	18	Overall, while I agree with general statements of the role and potential of solar energy, the section discussing the role of PV is presenting an incomplete picture and emphasizes aspects not according to their relevance. Overall, material seems to be drawn from relatively few and very specific sources, while many sources that are generally regarded to represent state of the art or define the standards in the field are ignored. Examples are extnesive reports from some of the leading instiutions, including the University of New South Wales, Fraunhofer ISE or the National Renewable Energy Laboratory. Many topics that have emerged within the last couple of years like the role of tandems, tracking systems, agro-photovoltaics or the developments on sector coupling and PV in a 100% renewable scenario have largely been ignored, while other topics like concentrating PV are covered in great deatil. This, to me, makes the report look distorted and lacking context (as mentioned above, for example, CSP power plants, which are extremely rare, are discussed but the status of conventional PV plant installations,m which contribute the majority of PV electricity is not even mentioned). In addition, some statements and numbers mentioned in the report are incorrect (for example the efficiency of GaAs solar cells or the role of perovskite solar cells for efficiency improvements). I am concerned that these issues with detail will compromise the overall trust in the report and will generate critizism that will distract from the important messages about what needs to be done to address climate change.	accepted - text has been completely rewritten	Ian Marius Peters	Forschungszentrum Jülcih	Germany
33277	29	10			In chpt 6.4.2.1 CSP should be separated completely in this chapter beacuse at the end it is very near a concentionel power plant. PV, CPV have specific question related to the access to the grid (inverters). Furthermore the technological questions are very different, with the development of the cell on which there is a large competition, which is not the case for CSP.	Accepted. CSP is now included in a separate subsection, "solar beyond PV." CPV is now briefly mentioned in the PV section.	Marc Darras	Association 4D	France

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41987	29	10			In 6.4.2.1. for solar energy, thermal updraft, with a big potential in developing countries for local production of electricity, should be included	Accpted. We now include mention and reference for "solar chimneys."	Francisco Javier Hurtado Albir	European Patent Office	Germany
39277	29	11	29	11	Is geophysical really the good term ? The paragraph talks more about georessources than geophysics.	changed for consistency	Bruno Gavazzi	UMR7516 Institut de Physique du Globe de Strasbourg (CNRS/Université de Strasbourg	France
43315	29	11	29	11	The world ocean is a very good absorber of solar energy. If we want a future energi source to be based on absorption of solar energy it is an obvious idea to do it at sea. This will be neutral to the energy balance of the globsl climate. Howeevr, locally/regionall it can have adverse effects on SST.	Accepted. Text revised to include floating solar	Aksel Walløe Walloe Hansen	Niels Bohr Intsitute, Uni. of Copenhagen	Denmark
9041	29	11	29	21	Solar energy potentials are not constant in time but vary on different timescales. This finding should be included here. Multi-decadal dimming and brightening, likely as a result of aerosol emissions has a considerable effect on surface radiation and consequently photovoltaic potentials (e.g., Wild 2016, Sweerts 2019). References Sweerts, B. et al. Estimation of losses in solar energy production from air pollution in China since 1960 using surface radiation data. Nat Energy 4, 657–663 (2019). Wild, M. Decadal changes in radiative fluxes at land and ocean surfaces and their relevance for global warming. WIREs Clim Change 7, 91–107 (2016).	accepted - text has been rewritten	Jan Wohland	ETH Zürich	Switzerland
43313	29	11	29	21	It is mentioned that in deserts very high values of solar input (~ 250 W/m2 or more). In nature most of this energy is reflected again because of the high albedos in deserts. For instance Sahara is a net drain of energy in the climate system. Therefore, if we install very large solar absorber systems in deserts the lower albedo may change the desert to a net absorber. Which will change the regional climate.	Rejected - outside the scope of the section. The climate effects of energy installations are considered in BOX XX.	Aksel Walløe Walloe Hansen	Niels Bohr Intsitute, Uni. of Copenhagen	Denmark
34215	29	12	29	12	what is the objective of this graph? Does it present Power? Energy? Money?	Noted. The figure represents energy at the earth surface.	Antoine BONDUELLE	Climate Action Network France	France
9029	29	19	29	21	Why should tracking PV systems not harvest diffuse sunlight? The added benefit of tracking might be zero regarding the diffuse component of radiation but I doubt that tracking implies that the cell doesn't convert diffuse radiation any more.	Accepted - revised text no longer makes this claim.	Jan Wohland	ETH Zürich	Switzerland
34173	29		54		A comparative table of the same type as the one used for the storage technologies (p59) could help summarize these 25 pages of energy sources assessment. [suggestion ENSEEIHT INP]	Rejected - outside the scope of analysis and space.	Antoine BONDUELLE	Climate Action Network France	France
45433	29				While there is good discussion around solar PV and CSP, the section doesn't cover solar thermal for heating or drying (residential, commercial or industrial) or industrial applications. Is this because there is no large penetration of these technologies, or is there not a current push for innvoation in these areas?	Noted. But this section's focus is on power with only brief mentions of heat applications.	Girija Parthasarathy	Thermo King	United States of America
45435	29				Solar energy - what are recommendations, for which regions?	Rejected - outside the scope of analysis and space.	Girija Parthasarathy	Thermo King	United States of America
24327	30	1	30	1	This kind of map does not give any clue about the truly available amount of solar energy that we might extract. It is equivalent as saying that in a few hours the sun provides enough energy to power the whole world. This is just a qualitative information and it keeps giving false hope to people about the true capacity of solar energy.	Rejected. The map provides high spatial resolution of solar insolation and makes clear that solar resource varies by more than a factor of two depending on location.	Alan BURLOT	Commissariat à l'énergie atomique et aux énergies alternatives	France
5891	30	1			There is much repetiton in this section - and indeed within the chapter - so heavy editing would be beneficial to avoid the obvious problem of repetition and the text sections seemingly written by several different individual authors. Much of this descriptive stuff was covered in detail in IPCC SRREN (2011) that even though out of date, could be referenced here rather than just repeat the basics. Eg Box 6.6 could state what's new since AR5 and SRREN	accepted - text has been completely rewritten as suggested	Ralph Sims	Massey University	New Zealand
34185	30	4	30	5	Thermal solar as a far bigger installed capacity than concentrating solar http://www.iea-shc.org/data/sites/1/publications/Solar-Heat-Worldwide-2018.pdf#page=13&zoom=auto,-129,714 [suggestion ENSEEIHT INP]	Noted. But this section's focus is on power with only brief mentions of heat applications.	Antoine BONDUELLE	Climate Action Network France	France
318	30	4	30	10	Floating PV projects are increasing; we see several projects under construction, or under development worlwide. Such systems could also serve in water conservation	accepted - reference to floating PV added later in section	El Mostafa Jamea	MENA Renewables and Sustainability - MENARES	Morocco
34217	30	4	30	14	maybe improve these two paragraph by adding the time horizons and realism, and be more precise first that the PV revolution of costs relies on silicium baseed conversion. There should be no doubt that the winners are not "better technologies" but the ones with a more dynamic industry base.	accepted - text has been completely rewritten	Antoine BONDUELLE	Climate Action Network France	France
31425	30	4	30	31	This is somehow a repetition of what has been already introduced in 6.3. You may move this to there?!	accepted - text has been completely rewritten	Patrick Jochem	German Aerospace Center (DLR)	Germany
11535	30	4		7	The concept of concentrating solar photovoltaics is missing.	accepted - text revised	Arnulf JÄGER-WALDAU	European Commission, JRC	Italy

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
11537	30	9		10	The technology route to produce solar fuels is missing. E.g. steam reforming, eletrolysis, electrochemical, etc.	accepted - text revised	Arnulf JÄGER-WALDAU	European Commission, JRC	Italy
16967	30	11	30	12	Please give a clear defination of 'technical potential' before useing it.	accepted - text revised	Qing YANG	Harvard University	China
20353	30	11	30	14	better not use old literature (2017) in a so highly and dynamic field. Major improvement will be provskite/c-Si tandem PV modules which are right now close to market introduction: https://www.nature.com/articles/s41563-018-0115-4 ; https://onlinelibrary.wiley.com/doi/10.1002/solr.201900555	accepted - text revised	Christian Breyer	LUT University	Finland
27087	30	11	30	14	Increasing the efficiency is one way to improve the technical potential, another way is to increase the ability of solar cells to collect light. Two concepts that have been substantaiyll installed in the past years are bifacial cells and trackers. Please refer to: R. Guerrero-Lemus et al. Bifacial solar photovoltaics – A technology review https://www.sciencedirect.com/science/article/abs/pii/S1364032116002768 (bifacial) and Ran Fus (NREL) Economic Models for Tracking systems.	accepted - text revised	Ian Marius Peters	Forschungszentrum Jülcih	Germany
27089	30	11	30	14	The report states "The most important development in this domain is the development of perovskite soalr cells" as a measure to improve conversion efficiencies. In this form, the statement is wrong. Perovskite solar cells by themselves can not be expected to achieve efficienices that are higher than those achieved with exisiting technologies, including silicon. The prospect of higher efficiencies comes from the development of tandem solar cells. In tandems, several solar cells are stacked, allowing to reach higher conversion efficinecies. Perovksite solar cells are relevant here, because they could provide a partner cell for silicon technology to gerenate very efficienct silicn / perovskite tandems. There is also a possibility for a perovskite / silicon tandem. For this topic, please refer to: I. M. Peters et al., The Value of Efficiency in Photovoltaics, https://www.sciencedirect.com/science/article/abs/pii/S2542435119303721, S. Sofia, Roadmap for cost-effective, commercially-viable perovskite silicon tandems for the current and future PV market, https://pubs.rsc.org/--/content/articlehtml/2020/se/c9se00948e, and S. Sofia et al., Economic viability of thin-film tandem solar modules in the United States, https://www.nature.com/articles/s41560-018-0126-z/	accepted - text revised	Ian Marius Peters	Forschungszentrum Jülcih	Germany
27091	30	11	30	14	The biggest challenge for the succesful commercialization of perovskite solar cells is their stabiilty. Refer to I. M. Peters et al., The Value of Efficiency in Photovoltaics, https://www.sciencedirect.com/science/article/abs/pii/S2542435119303721	accepted - text revised	Ian Marius Peters	Forschungszentrum Jülcih	Germany
27093	30	11	30	14	The topic of smart system integration has been a major topic of the PV community. Topics like sector coupling and synergies with other renewable sources need to be mentioned. Especially consider the work of C. Breyer, for example On the role of solar photovoltaics in global energy transition scenarios, https://onlinelibrary.wiley.com/doi/full/10.1002/pip.2885, or Jacobson et al., https://www.sciencedirect.com/science/article/abs/pii/S0960148118301526	accepted - text revised	Ian Marius Peters	Forschungszentrum Jülcih	Germany
39661	30	11	30	14	It is not clear from this paragraph why further improvements in solar cell efficiency is needed for enhancing the technical potential and no reference to support the claim. Explain why the current, quite mature, silicon based PV industry has a limited technical potential.	accepted - text revised	Simon Davidsson Kurland	Chalmers University of Technology	Sweden
46377	30	11	30	14	Enhancing the technical potential for PVs would require improvement in conversion efficiency of the current market-dominant crystalline silicon solar cells, which have reached 26.7 % efficiency of conversion of sunlight to electricity in research cells (https://www.nrel.gov/pv/cell-efficiency.html). The most important development in this domain is the development of perovskite cells (Petrus et al. 2017, https://www.nature.com/articles/nnano.2015.90), which have recently reached lab-scale efficiencies of 25% (https://www.nrel.gov/pv/cell-efficiency.html). A very promising opportunity here is to develop high-performance multijunction solar cells in which two or more absorbing layers are used to harvest complementary regions of the solar spectrum, potentially boosting the efficiencies of research cells to practical levels of 32-40% with very little added cost (https://doi.org/10.1039/C7EE01232B, https://doi.org/10.1039/C7EE01232B, https://pubs.acs.org/doi/full/10.1021/acsenergylett.6b00405). This could be achieved by adding perovskite solar cell layers to the existing silicon cell technology to boost the current state-of-the-art performances, or by using a perovskite combined with another perovskite layer or another thin film photovoltaic technology (https://www.nature.com/articles/s41560-018-0190-4). Apart from the fundamental scientific challenges to develop these tandem concepts into robust and stable technologies, it may also be pragmatic to utilise smart system integration.	accepted - text revised	Samuel Stranks	University of Cambridge	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
36747	30	12	30	13	"The most important development in this domain is the development of perovskite cells (Petrus et al. 2017)." I also hope that perovskite will enter mainstream PV, but there are still material issues and there is no technology established yet to upscale perovskites. Therefore, I suggest to change this sentence into the following: "Enhancing the technical potential for PV is From a GHG mitigation point of view, the most important development in PV is the steady improvement of mainstream Si cells, including passivating contacts, and for future tandem applications the development of perovskite cells."	accepted - text revised	Pietro Altermatt	R&D Center of Trinasolar	Germany
9031	30	13	30	14	This sentence is not clear at all to me: “Apart from the fundamental scientific challenges such as these, it may also be pragmatic to rely on smart system integration.”	accepted - text revised	Jan Wohland	ETH Zürich	Switzerland
24325	30	13	30	14	The last sentence of the paragraph « it may also […] smart system integration. » is extremmely misleading as it hides a gigantic part of the whole energy system design. Either remove the sentence or dramatically enhance the paragraph to remove the elusive character of the sentence.	accepted - text revised, we no longer use this term and refer readers to section 6.4.6	Alan BURLOT	Commissariat à l'énergie atomique et aux énergies alternatives	France
31677	30	13	30	14	The last sentence of the paragraph « it may also […] smart system integration. » is extremely misleading as it hides a gigantic part of the whole energy system design. Either remove the sentence or dramatically enhance the paragraph to remove the elusive character of the sentence.	accepted - text revised, we no longer use this term and refer readers to section 6.4.6	Alan BURLOT	Commissariat à l'énergie atomique et aux énergies alternatives	France
36749	30	13	30	14	I don't understand what yo mean with "Apart from the fundamental scientific challenges such as these, …" Mainstream Si PV technology is certainly sufficient mature not to have any fundamental scientific challenges anymore. It is being scaled up and it will be the main technology for GHG mitigation. If we introduce a new PV technology today and scale it up with 45% growth annually until 2050, this new technology will reduce GHG emissions by a minor amount compared to scaling up mainstream Si PV by 20% annually for the next 10 years and by consideably less than 20% the following years.	accepted - text revised	Pietro Altermatt	R&D Center of Trinasolar	Germany
14469	30	14	30	14	Explain or give an example to help readers understand what is "smart system integration".	accepted - text revised	Jean-Sébastien Landry	Environment and Climate Change Canada	Canada
9033	30	15	30	17	I suggest to specifically mention that CSP is a potentially dispatchable renewable technology (on timescales of a couple of hours up to a day or so) because this dispatchability can be used to faciliate grid integration of other renewables also. Pfenninger (2014) argue along these lines. Pfenninger, S. et al. Potential for concentrating solar power to provide baseload and dispatchable power. Nature Clim Change 4, 689–692 (2014).	accepted - text revised	Jan Wohland	ETH Zürich	Switzerland
14201	30	15	30	17	"One advantage of CSP is its scalability. Another is storage. CSP plants can be constructed to maintain substantial thermal storage, which is valuable for load balancing over the diurnal cycle" Please add also that the seasonal variability in real plants is worse than for other RES such as wind or solar PV, see Fig3 for the case of real plants in Spain in de Castro, C., Capellán-Pérez, I., 2018. Concentrated Solar Power: Actual Performance and Foreseeable Future in High Penetration Scenarios of Renewable Energies. Biophys Econ Resour Qual 3, 14. https://doi.org/10.1007/s41247-018-0043-6	accepted - text revised	Iñigo Capellán-Pérez	University of Valladolid	Spain
310	30	15	30	26	I have worked on CSP projects since 2012, they presented then a good promise; however, their costs did not decrease as it was planned. The only advantage compated to much competitive Wind En and Solar PV was the storage and dispatchability. Currentlty, and as you may have learned from the Noor Midelt Solar Project, IPP developers are even comobining solar PV with electricial heaters to power thermal storage. Such systems reduced the costs PPA.	accepted - text revised	El Mostafa Jamea	MENA Renewables and Sustainability - MENARES	Morocco
16971	30	15	30	26	This paragragh introduces the impacts of DNI on CSP, but the abundance of solar resource should be the geographical factor for solar power generation rather than technical one (you also address the impacts of GHI on PV in the 'geographical' section). It should be noticed that the difference between geogaphical and technical is not equal to the different between CSP and PV. Please restructure 'geographical' and 'technical' section in a more logical way and better differs them.	accepted - text revised	Qing YANG	Harvard University	China
22915	30	15	30	26	This paragraph of assessing CSP technology, stops short of mentioning one of its disadvantages, that is, it occupies a huge land size, even for a 20MW project, let alone a 100MW plant, such drawback limits its wide and large deployments for commercial use.	accepted - text revised to add land use impacts	Xiusheng Zhao	Tsinghua University	China
27095	30	15	30	26	The section states that "One advantage of CSP is ist scalability". This is true for all solar technologies and should be stated at the beginning. Like this it could be misinterpreted as CSP being scalable and other solar technologies aren't.	accepted - text revised	Ian Marius Peters	Forschungszentrum Jülcih	Germany
27097	30	15	30	26	It is stated that CSP can deliver large-scale power plants up to 300MW. The whole section about CSP seems to be out of context - the largest conventional PV installations are well above 1GW today, and future plants will be much larger (plannings go up to 5GW) see for example, https://www.pv-magazine.com/2019/01/14/planned-5-gw-indian-solar-plant-will-be-the-worlds-largest/ or https://www.power-technology.com/features/the-worlds-biggest-solar-power-plants/. Omitting this information will create a distorted picture of what different technologies can provide.	accepted - text revised	Ian Marius Peters	Forschungszentrum Jülcih	Germany

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
312	30	15	30	31	CSP applications for process heat in industry have more potential that its applications and deployment for power generation	response updated	El Mostafa Jamea	MENA Renewables and Sustainability - MENARES	Morocco
1219	30	15			Provide reference	accepted - text revised	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
44773	30	17	30	18	”Moreover, as with PV, CSP is also known to have significant societal advantages such as the prospects of large employability of workers (Islam et al. 2018).” The issue of increased employment is interesting and worthy of an extended discussion, especially in cases where one option leads to more people working with producing the same amount of electricity than if the electricity had been produced with a different options.	accepted - we drop this claim	Daniel Westlén	Liberal party Swedish parliament	Sweden
44775	30	17	30	18	”Moreover, as with PV, CSP is also known to have significant societal advantages such as the prospects of large employability of workers (Islam et al. 2018).” The refered article (Islam et al. 2018) is a relevant reference in itself, but for the present sentence the data for number of employments and CO2 savings are taken from an estimate by Greenpeace and not by Islam et al.	accepted - we drop this claim	Daniel Westlén	Liberal party Swedish parliament	Sweden
16969	30	21	30	21	I suppose it refers to Fig 6.13 rather than Fig. 6.3	accepted - we no longer use this figure	Qing YANG	Harvard University	China
19615	30	21			"of regions (Figure 6.3)." Figure 6.13?	accepted - we no longer use this figure	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	China
9533	30	27	31	2	The term "solar thermal technologies" may create confusion, as the class described here produces eletricity just like PV and actual solar technologies exist that produce heat.	accepted - text revised	Tom Kram	PBL (Fellow)	Netherlands
16973	31	2	32	2	The formation is not uniform among Figure 6.13, Table 6.5 and Figure 6.14 (the usage of 'source', if the full stop at the end of the title), please make sure format unification for all figures and tables.	accepted - figures replaced	Qing YANG	Harvard University	China
27099	31	4	31	11	The efficinecy numbers stated in this section are misleading, some are even wrong. Sunlight to electricity conversion is stated with a vlaue of between 10% and 20%, yet panels below 15% are hardly economic at all today, and many panels have efficiencies above 20%. No single junction solar cell (i.e. soalr cell made of just one material) has achieved 40%. The highest efficinecy for a GaAs solar cell is 29.1% under normal light and 29.3% under concentration. Multijuntion (als called tandem) solar cell stack different materials. Highest efficiencies here are 39.2% for a solar cell made of 6 different materials under normal light and 47.1% under concentration. A reliable source for solar cell efficiencies is the Solar Efficiency Table of M. Green https://onlinelibrary.wiley.com/doi/10.1002/pip.3228	accepted - text revised	Ian Marius Peters	Forschungszentrum Jülcih	Germany
36751	31	4	31	11	This paragraph misses major points entirely and is making false claims. What is false: "Large scale installations can also be a problem due to the removal of large areas of land use". Firtly, open-pit coal mines use far more land per gained kWh of electricity than PV does, and it is such mining that PV mainly replaces. Hence, the land use will decrease with the energy transition. Secondly, you've just shown above in the technological section (page 30, line 4, also fig. 6.13) how big the averaged irradiation per area is. This implies that a tiny, tiny fraction of land needs to be covered to supply all energy worldwide. What is implicitely false: "However, when using newer materials such as GaAs (Gallium Arsenide), solar cell efficiency had achieved a 40% at the end of 2010". This is not true. GaAs also has the Shockley-Queisser limit, the highest efficiency in your reference (Kumar Sahu 2015, why did you choose that reference?) is 29.1%. GaAs is a scarce material and cannot contribute significantly to GHG emission mitigation due to supply risks, as has been shown by many papers on material resources, availability and price risks. There is no GaAs PV industry.	accepted - text revised	Pietro Altermatt	R&D Center of Trinasolar	Germany
36753	31	4	31	11	For these reasons, I suggest to replace this entire paragraph from line 4 to 11 with something along these lines: "Mainstream PV has become competitive to fossil fuels due to various contributions. (i) price decay with a learning rate of 23% from 1976 to 2018 ("International Technology Roadmap for Photovotlaic (ITRPV), 2018 Results, itrpv.vdma.org), (ii) modular deployment with the least time and budget overruns of all major power technologies (Alexander Gilbert et al.,"Cost overrunsand financial risk in the construction of nuclear power reactors: A critical appraisal", Energy Policy102(2017) 644–649); (iii) resource availability of silicon and all involved materials in silicon PV except silver and tin, which can easily be substituted by copper and by other soldering agents (G. Kavlak et al, "Metal production requirements for rapid photovoltaics deployment", Energy Environ. Sci. 8, 1651 (2015);S imon Davidsson and Mikael Höök, "Material requirements and availability for multi-terawatt deployment of photovoltaics", Energy Policy 108 (2017) 574–582). (iv) High reliability due to no or hadly any movable mechanical parts, encapsulation of modules, and standard technology, with manufacturer's garantees given typically for 25 to 30 years and 0.5% relative efficiency degradation per year, leading to low weighted average cost of capital (WACC) (IRENA 2019).	accepted - text has been completely rewritten as suggested	Pietro Altermatt	R&D Center of Trinasolar	Germany
43317	31	4	31	11	Electricity from solar installations is a rather extensive source. In line 10 it is mentioned that 1 MW requires an area of 4-6 acres. In many countries this requirement will be much higher. A table with numbers for variuous palces on Earth would give a better perspective.	accepted - text has been completely rewritten	Aksel Walløe Walloe Hansen	Niels Bohr Intsitute, Uni. of Copenhagen	Denmark

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34219	31	4	31	25	these paragraphs could be uptdated notably with IRENA 2019. Solar power is now under 0.10$/kWh in many cases, this figure line 16 is outdated	accepted - text revised - all cost values now up to date with 2019 data	Antoine BONDUELLE	Climate Action Network France	France
16975	31	4	32	21	Please also give the introduction of CSP from economy perspective rather than PV only, or explain why CSP is excluded in this section.	accepted - text has been completely rewritten	Qing YANG	Harvard University	China
11541	31	5		6	between 2009 and 2019 LCOE decrased by 77% (https://doi.org/10.3390/en13040930)	accepted - text revised - all cost values now up to date with 2019 data	Arnulf JÄGER-WALDAU	European Commission, JRC	Italy
44091	31	5			After the word "scale", add; "the Egyptian plant in Binban of Aswan (1.65 GWh) is an example."	accepted - text no longer contains the passage referred to	Mohammad Fahmy Ramadan	Head of Civil & Architecture Branch, MTC, Cairo, Egypt	Egypt
20355	31	6	31	8	the comment on low conversion efficiency is nonsense, sorry to say! Please compare to bioenergy: the solar-to-biomass efficiency is about 1%, then the combustion in a plant with 50% at best delivers 0.5% and PV is able for 20% which is a factor of 40!!! Better revise such rather non-scientific stuff; another nice example is floating PV on hydro reservoirs. Only 25% of area coverage is enough for an alpine hydro reservoir to produce MORE PV electricity over the year then via hydropower, as shown by Farfan and Breyer (https://www.sciencedirect.com/science/article/pii/S1876610218309858)	accepted - text has been completely rewritten	Christian Breyer	LUT University	Finland
39663	31	6	31	9	The relevance of the claim that the "sunlight-to-electricity" efficiency is 10-20% "in most cases" for PV is questionable as currently dominating c-Si solar cells tend to be towards the higher parts of this range. It is strange to not mention that c-Si PV completely dominate the PV market despite the potentially higher efficiency of some other technologies, with very limited market share.	accepted - text has been completely rewritten	Simon Davidsson Kurland	Chalmers University of Technology	Sweden
1649	31	7	31	7	repetition of 'terms of'	accepted - text has been completely rewritten	Jenkins Rhosanna	University of East Anglia	United Kingdom (of Great Britain and Northern Ireland)
44383	31	7			typo: "efficiency in terms of terms of" should be "efficiency in terms of"	accepted - text revised	Pietro Guarato	University of Lausanne	Switzerland
45373	31	8	31	8	the 10-20% figure is outdated. Lowest commercailly available modules are 16%- 20% with top quality modules reaching 23%. 15-23% is a more accurate range. New bifacial modules can garner additioal yields	accepted - text has been completely rewritten	Deborah Knuckey	Published energy journalist plus consultant for renewable energy development and finance companies through Kiterocket	United States of America
9035	31	8	31	9	Comparing efficiencies of very expensive high-efficiency cells that were probably operated in lab-type conditions with cost-competitive and widely deployed silicon cells does not seem fair.	accepted - text has been completely rewritten	Jan Wohland	ETH Zürich	Switzerland
18613	31	8	31	9	The mention of recent achievements in high efficiency PV technologies is important, but limiting it to one source from 2015 (for the year 2010) for a single technology is not really meaningful. You may consider using the latest version of the National Renewable Energy Laboratory's "Best Research-Cell Efficiency Chart", available at https://www.nrel.gov/pv/cell-efficiency.html to get a better overview of improvements across the families of PV technologies.	accepted - text revised; all values and refs updated.	Thomas Gibon	Luxembourg Institute of Science and Technology (LIST)	France
20359	31	8	31	9	why no one with real knowledge about PV wrote the PV parts!? PV is one of the most important technologies for the energy transition but obviously very little PV knowledge had been available while writing! This is really weak. Use the latest PV world efficiency overview from Martin Green (https://onlinelibrary.wiley.com/doi/10.1002/pip.3228), which is known by PV experts quite well	accepted - text revised; all values and refs updated.	Christian Breyer	LUT University	Finland
11539	31	8		11	GaAs is used cor concentrating solar PV and only a niche market. The proper refernce for solar cell/module efficiencies woyld be the solar cell efficiency tables (https://doi.org/10.1002/pip.3228); The current top efficiency is abofe 47% for a AlGaInP/AlGaAs/GaAs/GaInAs multijunction cell, not a module.	accepted - text revised	Arnulf JÄGER-WALDAU	European Commission, JRC	Italy
20357	31	9	31	11	SI units should be standard in scientific literature; remove acres and convert to km2 or hectar if needed	accepted - text revised	Christian Breyer	LUT University	Finland
11545	31	9		11	The rooftop potentials (e.g. DOI: 10.1016/j.rser.2019.109309) as well as alternative applications like floating PV or dual use of infrastructure or mining areas (DOI: 10.3390/su11133703) is missing. Lower numbers that the one cited are also possible; see https://www.nrel.gov/docs/fy13osti/56290.pdf	accepted - reference to floating PV added	Arnulf JÄGER-WALDAU	European Commission, JRC	Italy
13841	31	10	31	10	It would be advisable to use the metric system in this context ? Around "2 Ha" or "20 000 m²" instead "4 to 6 acres"	accepted - text revised	Alexandre Bizeul	International Energy Agency	France
14471	31	10	31	11	"[F]or 1 MW of solar electricity production"; MW is a measure of capacity, not production.	accepted - text revised	Jean-Sébastien Landry	Environment and Climate Change Canada	Canada
20361	31	12	31	17	lack of market data is shocking for the PV section. Use latest literature from PV experts, as published by Vartiainen et al. (https://onlinelibrary.wiley.com/doi/full/10.1002/pip.3189); see cost numbers of IEA-PVPS on PV tenders, which speak really a COMPLETELY different language - Table 3.3 in the latest trends report 2019 (http://www.iea-pvps.org/index.php?id=trends)	accepted - text revised - all cost values now up to date with 2019 data	Christian Breyer	LUT University	Finland

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
27101	31	12	31	17	The report later on quotes the very well researched study by Ran Fu (2018 cost benchmark). This source should also be used here, as it provides more recent numbers. It should be noted that LCOE varies significnatly with inslattaion costs, which can be very differen, and tend to be high in industrialized countried (see I. M. Peters et al., The Value of Efficiency in Photovoltaics, https://www.sciencedirect.com/science/article/abs/pii/S2542435119303721).	accepted - text revised - all cost values now up to date with 2019 data	Ian Marius Peters	Forschungszentrum Jülcih	Germany
27103	31	12	31	17	A relevant source that could be mentioned here is the study by Creutzig et al., https://www.nature.com/articles/nenergy2017140 which points out that the growth of PV has in the past always been underestiamted.	accepted - text revised - all cost values now up to date with 2019 data	Ian Marius Peters	Forschungszentrum Jülcih	Germany
46081	31	12	31	25	There should be info on price for tenders for large solar projects, which points to much lower costs of large solar PV installations, for example http://helioscsp.com/price-of-concentrated-solar-power-to-drop-to-60-mwh-by-2020-irena-predicts/	accepted - text revised - all cost values now up to date with 2019 data	Neven Duic	University of Zagreb	Croatia
45375	31	14	31	16	2017 figures are relatively old - substantial declines in the last couple ofeyars - new source available? Recent auctions have been as low as 0.02 $/kWh (and a few outliers even lower: https://pv-magazine-usa.com/2020/01/24/qatars-800-mw-tender-draws-world-record-solar-power-price-of-0-01567-kwh/)	accepted - text revised - all cost values now up to date with 2019 data	Deborah Knuckey	Published energy journalist plus consultant for renewable energy development and finance companies through Kiterocket	United States of America
20363	31	18	31	25	it gets worse and worse! Use latest PV capex numbers from IEA-PVPS (http://www.iea-pvps.org/index.php?id=trends) Table 6.1, with MUCH lower numbers, and also consider the detailed discussion of PV experts, published in the leading scientific PV journal (https://onlinelibrary.wiley.com/doi/full/10.1002/pip.3189)	accepted - text revised - all cost values now up to date with 2019 data	Christian Breyer	LUT University	Finland
24329	31	18	31	25	Does the cost takes into account the fact that PV panels are produced using coal in Germany and China ? The environmental impact of those panels are not well quantified or not expressed.	accepted - text revised - section on Life cycle analysis results added.	Alan BURLOT	Commissariat à l'énergie atomique et aux énergies alternatives	France
39173	31	18	31	25	The PV costs used here from 2017 are well out of date and even further out of date by 2021. Please use a modern reference such as https://doi.org/10.1002/pip.3189 - these results strongly affect the costs of mitigation.	accepted - text revised - all cost values now up to date with 2019 data	Tom Brown	Karlsruhe Institute of Technology	Germany
15055	31	22	31	24	missing spaces - the same problem four times ($/kWh)	accepted - text revised - units corrected	Béla Munkácsy	ELTE University	Hungary
27105	31	22	31	25	A good source for the status of PV in germany is her PV status report by Fraunhofer ISE; https://www.ise.fraunhofer.de/content/dam/ise/de/documents/publications/studies/Photovoltaics-Report.pdf Numbers are similar but more recent	accepted - text revised - all cost values now up to date with 2019 data	Ian Marius Peters	Forschungszentrum Jülcih	Germany
11543	31	23		25	Newer numbers are available. The reason for the high system price in CA is missing, e.g. tax breakes, etc	accepted - text revised - all cost values now up to date with 2019 data	Arnulf JÄGER-WALDAU	European Commission, JRC	Italy
14203	31		31		Table 6.5. Among the disadvantages, please include that solar technologies on land are hardly compatible with double uses, which makes that their land ocupation at high penetartion levels may be a problem in some circumstances: MacKay, D.J.C., 2013. Solar energy in the context of energy use, energy transportation and energy storage. Philosophical Transactions of the Royal Society of London A: Mathematical, Physical and Engineering Sciences 371, 20110431. https://doi.org/10.1098/rsta.2011.0431 Smil, V., 2015. Power Density: A Key to Understanding Energy Sources and Uses. The MIT Press, Cambridge, Massachusetts. Capellán-Pérez, I., de Castro, C., Arto, I., 2017. Assessing vulnerabilities and limits in the transition to renewable energies: Land requirements under 100% solar energy scenarios. Renewable and Sustainable Energy Reviews 77, 760–782. https://doi.org/10.1016/j.rser.2017.03.137	accepted - new section on land use added.	Iñigo Capellán-Pérez	University of Valladolid	Spain
16669	31		33		The cost per installed kWh is not always relevant. For a village in a developping coutry far from any grid, a local system with a dedicated end use, e.g. pumping water, should be affordable (modest insvestment) whatever the cost per kWh is. Solar thermal is still ignired.	accepted - text revised - all cost values now up to date with 2019 data	Jean Louis Bobin	Sorbonne universités Paris	France
46083	32	1	31	1	Some significant countries are missing with very low solar costs, like Saudi Arabia, UAE, Brazil etc.	accepted - text revised - all cost values now up to date with 2019 data	Neven Duic	University of Zagreb	Croatia
28869	32	1	32	1	figure 6.14. I saw exactly the same figure on Chapter 1. It feels very reduntant for me (although, it is ok too). I think you need to communicate with someone who wrote the chapter 1 about where to place this figure. Maybe chapter 1 need to only summarize the explanation of this figure on chapter 6.	accepted - text revised - all cost values now up to date with 2019 data	Marissa Malahayati	National Institute for Environmental Studies	Japan
28871	32	1	32	1	Like Figure 1.6, in Figure 6.14. US is divided into 4 region, I suggest to make it average so the figure is comparing the trend of several countries. If it possible kindly compare it with any other developing countries. It will be interesting and informative to compare the condition between developing and developed countries.	accepted - text revised - all cost values now up to date with 2019 data	Marissa Malahayati	National Institute for Environmental Studies	Japan
34221	32	1	32	1	the graph could be uptdated with the same one published one year later	accepted - text revised - all cost values now up to date with 2019 data	Antoine BONDUELLE	Climate Action Network France	France

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314	32	4	32	21	The duration of PV systems operation influence the PPA. For example, in SSA while the solar radiation could optilimize power production, the hot weather conditions would influence the life time of solar cells and electronics equipements	accepted - text revised - all cost values now up to date with 2019 data	El Mostafa Jamea	MENA Renewables and Sustainability - MENARES	Morocco
20365	32	7	32	15	mentioned PV cost are mostly wrong. Take real numbers approved by PV experts around the world - and sent by national Energy Ministries - for the IEA-PVPS (http://www.iea-pvps.org/index.php?id=trends) - take there from Tab. 6.1 and Fig. 6.1 real numbers, AND differentiate between the four main market segments: utility-scale power plants, rooftop systems for residentical, commercial, industrial	accepted - text revised - all cost values now up to date with 2019 data	Christian Breyer	LUT University	Finland
39175	32	9	32	9	“reporting” → “reported”	Accepted - text revised - wording no longer used.	Tom Brown	Karlsruhe Institute of Technology	Germany
6259	32	10	32	10	The Table referred is missing it would be cited as Table 6.6, not Table 6. The same should apply to all Tables.	accepted - table removed .	Brown Gwambene	Marian University College	United Republic of Tanzania
19617	32	10			"(see Table 6.)." Table 6.6?	accepted - table removed and references to it.	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	China
14473	32	11	32	12	What does "Wdc" stand for?	Accepted - text revised - acronym no longer used.	Jean-Sébastien Landry	Environment and Climate Change Canada	Canada
27107	32	12	32	15	Numbers given here are for the US, which traditionally has high costs for residential PV installations. The previous page states numbers for Germany and China, which are at about $1.3/W. It should be made clear that the numbers stated on this page are for the US and the Way numbers are reported should be consistent throughout the report (either $/W or $/kW).	accepted - text revised - all cost values now up to date with 2019 data	Ian Marius Peters	Forschungszentrum Jülcih	Germany
36755	32	15	32	15	your system cost may need updating as they have been falling, see IRENA 2019. Your reference (Kavlak et al 2018) had a substantial response letter, see Martin A. Green, "How Did Solar Cells Get So Cheap?", Joule 3, 631–640 (2019) and should be included as well if you decide to keep the Ref. of Kavlak (better to use the latest IRENA data).	accepted - text revised - all cost values now up to date with 2019 data	Pietro Altermatt	R&D Center of Trinasolar	Germany
20367	32	16	32	21	any ordinary literature research of students could deliver better results - it is unbelievable. See real literature to the cost and benefit of PV systems: Vartiainen et al. (https://onlinelibrary.wiley.com/doi/full/10.1002/pip.3189), Gerlach and Breyer (https://onlinelibrary.wiley.com/doi/abs/10.1002/pip.1254) and Keiner et al. (https://www.sciencedirect.com/science/article/pii/S0038092X19304281)	accepted - text revised - all cost values now up to date with 2019 data	Christian Breyer	LUT University	Finland
31427	32	16	32	21	You may integrate a paper here: “Also national comparisons of the profitability of PV storage applications in domestic applications show the significant differences of the jurisdictions – in some countries these applications are already profitable, in others not (Kazhamiaka et al., 2017).” Kazhamiaka, Fiodar, et al. "On the influence of jurisdiction on the profitability of residential photovoltaic-storage systems: A multi-national case study." Energy Policy 109 (2017): 428-440, https://doi.org/10.1016/j.enpol.2017.07.019	accepted - text revised	Patrick Jochem	German Aerospace Center (DLR)	Germany
25067	32	20	32	21	Delete "This indicates the need … (Ondraczek et al. 2015)." as alternative energy sources should be considered based on national circumstances, rather than horizontal approaches of subsidising renewables	accepted - text revised	Eleni Kaditi	Organization of the Petroleum Exporting Countries (OPEC)	Austria
36757	32	21	32	21	Why do you describe the situation only in the US where PV is very expensive? In many countries, PV is installed subsidy-free.	accepted - text revised - all cost values now up to date with 2019 data	Pietro Altermatt	R&D Center of Trinasolar	Germany
9535	33	1	33	2	In Table 6.6 "higher module cost" is included to explain increasing cost, but its obvious counterpart "lower module cost" is missing from options to decrease the price. To restore the balance it may be better to drop this all too obvious, aggregate source of cost in/decreases.	accepted - table removed .	Tom Kram	PBL (Fellow)	Netherlands
11353	33	1	33	2	Clarity in Table 6 is lacking. Event of decrease and increase should be presented to make it easily understandable. Bullet points are actually factors affecting the cost of solar module. Table may therefore be upgraded/ modified from Fu et al.’ 2018.	accepted - table removed and references to it.	PINAKI SARKAR	CSIR-CENTRAL INSTITUTE OF MINING AND FUEL RESEARCH	India
32265	33	1	33	2	On could cite the "multifuction" panels (eg solar tiles) as a powerfull way for decresing the total services costs in the domestic, commercial or industrial sectors	Accepted - now included.	Jean-Guy Devezeaux de Lavergne	Commissariat à l'Energie Atomique et aux Energies Alternatives	France
20369	33	3	33	12	the presented picture with high integration cost is in strong violation to 100% renewables research by Bogdanov et al. (https://www.nature.com/articles/s41467-019-08855-1) who show for full hourly resolution for 145 regions in the world a high solar PV share, AND lower cost for the entire system than at present - the integration cost are first lower than anticipated and second massively offset by very low PV cost - a more up-to-date literature knowledge would be really helpful for the entire PV section! Similar results for Europe from Child et al. (https://www.sciencedirect.com/science/article/pii/S0960148119302319), including PV prosumers, which have been not yet mentioned in the entire section.	Acepted - grid integration costs have been udpated	Christian Breyer	LUT University	Finland

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
27109	33	3	33	12	This section mostly represents understanding as fo 2015. Statements are based on considerations of PV systems in isolation, but are not considering sector-coupling and other synergistic effects. The cost for integration of solar into a broader system has been investigated extensively for example by Breyer et al., (for example https://www.sciencedirect.com/science/article/pii/S0960148119302319), Jacobson et al. (https://www.sciencedirect.com/science/article/abs/pii/S0960148118301526), Teske et al. (https://www.springer.com/gp/book/9783030058425), Pursiheimo et al. (https://www.sciencedirect.com/science/article/abs/pii/S096014811831156X) or Sgouridis et al. (https://iopscience.iop.org/article/10.1088/1748-9326/11/9/094009).	Acepted - Sector-coupling mentioned; reader is referred to 6.4.6 for more on system integration	Ian Marius Peters	Forschungszentrum Jülcih	Germany
27111	33	3	33	12	In this section, but overall in the chapter, battery storage is mentioned predominantely as the most viable storage option. The role of other storage technologies, especially pumped hydro (which is the by far most common stationary storage and is capable of storing enrgy long time) should be included more prominently. See for example: https://search.informit.com.au/documentSummary;dn=437215428609125;res=IELENG, http://energy.anu.edu.au/files/Senate%20submission%20-%20ANU%20pumped%20hydro%20energy%20storage%20030217_0.pdf, http://re100.eng.anu.edu.au/global/	Accepted - storage is discussed in this section in general; more detailed information on storage technolgies is given in 6.4.3	Ian Marius Peters	Forschungszentrum Jülcih	Germany
39177	33	3	33	12	The integration costs here are out of date (2015) and therefore exaggerated. For example, Fasihi et al https://doi.org/10.1016/j.jclepro.2019.118466 see much lower system LCOE for PV-dominated systems, so USD 80/MWh integration costs is way too high. What about demand response? Sector integration? Today's battery storage cost are 250 USD/kWh not 250 USD/MWh (units error).	accepted - text revised	Tom Brown	Karlsruhe Institute of Technology	Germany
13845	33	4	33	5	As it is not further explained in this chapter, it may be useful to define in one line what are integration costs. Suggestion : "First, the integration costs, that are not included in the standard LCOE definition such as decrease in utilisation rates of other powerplants, curtailments, grid reinforcements or balancing are estimated to be high – 5 up to 50% of total costs in scenarios with high penetration (Hirth et al. 2015).".	accepted - text revised	Alexandre Bizeul	International Energy Agency	France
36759	33	4	33	5	"First, the costs of integration are estimated to be high...". Again, please take the systematically collected data from IRENA and from Integrated Assessment Modeling like: http://energywatchgroup.org/new-study-global-energy-system-based-100-renewable-energy . I am not an expert in economical aspects, but I doubt the numbers in this paragraph, I think they need an update. A counter example: Germany has more than 40% renewables, Demnark even higher, and I cannot see such high costs.	accepted - text revised	Pietro Altermatt	R&D Center of Trinasolar	Germany
9037	33	4	33	12	This paragraph forgets to mention that generation variability can be substantially reduced with renewable portfolios and that other strategies to cope with generation variability (such as transmission and sector coupling) exist. For instance, it is well established that the seasonal cycles of wind and solar power generation in Europe are different and optimum relative shares allow to provide a more stable renewable feed-in. Example Reference: Heide, D. et al. Seasonal optimal mix of wind and solar power in a future, highly renewable Europe. Renewable Energy 35, 2483–2489 (2010).	Accepted - Seasonal cycle mentioned, sector coupling mentioed; reader is referred to section 6.4.6 for more on system integration	Jan Wohland	ETH Zürich	Switzerland
6357	33	5	33	5	Please define clearly what 'total costs' means. Is this the CAPEX?	accepted - text revised	Sciacovelli Adriano	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
43679	33	5			While the Hirth source is correct about the issue, it is taken old numbers for gauging their estimate. Hence the 50% is mostly likely incorrect. It could be good to ask the ESM community for their estimates.	accepeted - updated literature now included	Felix Creutzig	MCC Berlin	Germany
20371	33	7	33	12	the discussion on PV curtailment is not up-to-date and literature insights are missing. Check Bogdanov et al. (https://www.nature.com/articles/s41467-019-08855-1) with one of the highest PV penetrations published, but for full hourly resolution in an optimised energy system - curtailment cost are rather small. Similar insights are found by Solomon et al. (https://www.sciencedirect.com/science/article/pii/S0306261918317756) for the penetration-storage-curtailment nexus. See here a publication of India with one of the highest PV share every reported, but in full hourly resolution and also full monsoon mitigation (https://www.sciencedirect.com/science/article/pii/S2352152X17304334 ; https://digital-library.theiet.org/content/journals/10.1049/iet-rpg.2019.0603). The unbalanced literature knowledge requires major revision.	Accepted - text updated	Christian Breyer	LUT University	Finland
31805	33	10	33	11	Battery prices currently cost around $250/kWh, not MWh. And they are expected to reduce to $100 / kWh by mid to late 2020s, and not mid-century. That is a big difference!	Accepted - storage is discussed in this section in general; more detailed information on storage technologies is given in 6.4.3 [Check section number]	Ashok Sreenivas	Prayas (Energy Group)	India

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
27113	33	13	33	23	This secion mentions a few of the many effects that the installation of solar panels may have on the environment and is limited to contributions from two sources from one main author. Much of the more recent work, for example on agro-photovoltaics is completely neglected. Solar Panels may, for example, have a positive impact on the ability of soil to store water (see for example https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0203256 or https://www.hydrol-earth-syst-sci.net/22/1285/2018/hess-22-1285-2018.pdf)	accepted - text on environmental impacts has been completely rewritten	Ian Marius Peters	Forschungszentrum Jülcih	Germany
39665	33	13	33	23	The paragraph about environmental impacts of solar power should be expanded. There are many potential environmental implications of producing PV modules, for instance relating to mining, but these can vary greatly depending on which technologies are used. It is mentioned that recycling can prevent some impacts, but the impacts are not described in detail and without any references.	accepted - text on environmental impacts has been completely rewritten	Simon Davidsson Kurland	Chalmers University of Technology	Sweden
12895	33	13	33	28	Cost estimates of environmental impacts may be added	accepted - text on environmental impacts has been completely rewritten	ASHOK NEMA	Nuclear Power Corporation of India Limited	India
34155	33	13	33	28	No mention of the environmental cost of extracting rare earth in this part http://scholar.google.fr/scholar_url?url=https://www.mdpi.com/2079-9276/3/1/123/pdf&hl=fr&sa=X&scisig=AAGBfm2vxu5QKl5HIG4G3Er3Q7RtAvQ2Fw&nossl=1&oi=scholarr [suggestion ENSEEIHT INP]	accepted - text on environmental impacts has been completely rewritten	Antoine BONDUELLE	Climate Action Network France	France
39179	33	18	33	19	"water is required for panel washing and dust suppression" - this is not always true, see e.g. https://spectrum.ieee.org/energy/renewables/the-pros-and-cons-of-the-worlds-biggest-solar-park in India where mechanical or robotic methods are used to clean panels	accepted - text on environmental impacts has been completely rewritten	Tom Brown	Karlsruhe Institute of Technology	Germany
20373	34	1	34	7	better use latest data for PV learning rates, as provided by Vartiainen et al. (https://onlinelibrary.wiley.com/doi/full/10.1002/pip.3189)	accepted - text revised - all cost values now up to date with 2019 data.	Christian Breyer	LUT University	Finland
39667	34	5	34	7	Define which time period is refered to for the learning curves and motivate why coal a suitable comparison to PV.	accepted - text revised - all cost values now up to date with 2019 data; dropped comparison to coal	Simon Davidsson Kurland	Chalmers University of Technology	Sweden
19847	34	6	34	6	For a comparison, learning rates of coal and solar PV have to be similar i.e., both in simply numbers or in %	accepted - text revised - all cost values now up to date with 2019 data; dropped comparison to coal	Ghulam Rasul Athar	Pakistan Atomic Energy Commission	Pakistan
19619	34	6			"power plants was 6-10," 6-10%?	Editorial	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	China
18689	34	8	34	8	Solar energy, through a variety of applications (e.g. rooftop solar), has the potential to meet as high as half of the global energy demands.'. It is challenging to see this from the perspective of the UK or other nothern latitute countries where solar is ill-matched seasonally and within a day to increased energy demand. Thus - there would need to be significant oversizing and storage to meet more of the demand. This will clearly be different in other countries, where the solar resource is better matched seasonally and within day to the demand. A reference to back up the original statement would be helpful.	accepted - text revised - no claims made about share of energy supply in this section; see cost and potentials section as well as adoption in 6.3	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
9039	34	8	34	9	Where does this number come from (50% of global energy demand)? Are we talking about technological potentials or does this reflect, for example, land use restrictions? I believe that this sentence has to be made more specific.	accepted - text revised - no claims made about share of energy supply in this section; see cost and potentials section as well as adoption in 6.3	Jan Wohland	ETH Zürich	Switzerland
37399	34	8	34	9	In theory and without cost considerations, solar energy could supply much more. Indeed, there is a growing body of literature showing cost-effective energy systems with much higher renewable penetration rates. Please provide an explicit citation as to why this is limited to 50% or qualify sufficinetly (e.g., more than half)	accepted - text revised - no claims made about share of energy supply in this section; see cost and potentials section as well as adoption in 6.3	Michiel Schaeffer	Climate Analytics	Netherlands
39669	34	8	34	9	The claim that half the global energy demand could be supplied by solar needs a reference, or be removed. This appears to be highly uncertain and could vary greatly with the considered constraints to technical potential.	accepted - text revised - no claims made about share of energy supply in this section; see cost and potentials section as well as adoption in 6.3	Simon Davidsson Kurland	Chalmers University of Technology	Sweden
20375	34	8	34	14	this statement that PV can cover half of energy need is wrong. Bogdanov et al. (https://www.nature.com/articles/s41467-019-08855-1) have shown 69% for the power sector; Ram et al. (http://energywatchgroup.org/wp-content/uploads/EWG_LUT_100RE_All_Sectors_Global_Report_2019.pdf) similar values for the entire energy system - which is also confirmed by Pursiheimo et al. (https://www.sciencedirect.com/science/article/pii/S096014811831156X) - BTW, Bogdanov et al. and Ram et al. have shown that for least cost systems in 2050, lower in cost than the present energy system - such important reseach insights require mentioning; similar discussion is availabe by global leading PV researchers published in Science (https://science.sciencemag.org/content/364/6443/836)	accepted - text revised - no claims made about share of energy supply in this section; see cost and potentials section as well as adoption in 6.3	Christian Breyer	LUT University	Finland
24331	34	8	34	14	Do we have an estimation of the cost of public subsidies per GW installed ? And a comparison with past public program like the nuclear one that started in the 70s ?	Rejected - outside the scope of the chapter - see ch 16 on innovation.	Alan BURLOT	Commissariat à l'énergie atomique et aux énergies alternatives	France

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
16267	34	18			In Section 6.4.2.2 Wind Energy, consider adding an analysis that describes the scarcity of rare earth elements (REEs) used in making the magnets for wind generation, and also the impact of increased production of these REEs in producing other REEs as byproduct, notably uranium, that can be used for nucear arms production if enrichment occurs. This information might be organized into a subsection titled [geopolitical] or something similar, as an aid to the reader.	Accepted. Text revised	Daniel Helman	College of Micronesia-FSM	Micronesia, Federated States of
15057	34	19	34	19	1 millio GW of wind energy capacity available	Accepted – text revised	Béla Munkácsy	ELTE University	Hungary
39279	34	19	34	19	Is geophysical really the good term ? The paragraph talks more about georessources than geophysics.	Changed for consistency	Bruno Gavazzi	UMR7516 Institut de Physique du Globe de Strasbourg (CNRS/Université de Strasbourg	France
43319	34	19	34	20	It is said that a total of 1 million GW = 1 PW is available as wind energy for the toal land coverage. 1 PW is a normal value for the total global wind energy dissipation. It seems impossible to extract more wind energy than nature itself is dissipating as heat.	Accepted – the text has been revised.	Aksel Walløe Walloe Hansen	Niels Bohr Intsitute, Uni. of Copenhagen	Denmark
24333	34	19	34	21	This sentence is vague and keeps telling the story that « the energy is here and everywhere around ». In my opinion, it has nothing to do in this kind of report. Or at least, it should be mentionned that it is only to give an indication of the amount of power that is available but only to get an order of magnitude in mind. This is extremmely misleading for non specalists, to my opinion.	Accepted – text revised	Alan BURLOT	Commissariat à l'énergie atomique et aux énergies alternatives	France
31679	34	19	34	21	This sentence is vague and keeps telling the story that « the energy is here and everywhere around ». In my opinion, it has nothing to do in this kind of report. Or at least, it should be mentioned that it is only to give an indication of the amount of power that is available but only to get an order of magnitude in mind. This is extremely misleading for non specalists, to my opinion.	Accepted – text revised	Alan BURLOT	Commissariat à l'énergie atomique et aux énergies alternatives	France
16977	34	19	34	24	According to the meaning of these sentences,the geophysical distribution of wind energy is based on onshore wind energy. This should be pointed out so as to make the sentence more clear.	Accepted – text revised	Qing YANG	Harvard University	China
9043	34	19	34	25	Wind power potentials are not constant but vary on different timescales. This includes multidecadal variability as reported from observations (Vautard 2010, Zeng 2019) and centennial reanalyses (Wohland 2019). References Vautard, R., Cattiaux, J., Yiou, P., Thépaut, J.-N. & Ciais, P. Northern Hemisphere atmospheric stilling partly attributed to an increase in surface roughness. Nature Geosci 3, 756–761 (2010). Zeng, Z. et al. A reversal in global terrestrial stilling and its implications for wind energy production. Nat. Clim. Chang. (2019) doi:10.1038/s41558-019-0622-6. Wohland, J., Omrani, N. E., Keenlyside, N. & Witthaut, D. Significant multidecadal variability in German wind energy generation. Wind Energ. Sci. 4, 515–526 (2019).	Taken into account. A new paragraph on variations of wind resources is now included. However, variations in larger time scales are considered in section 6.5.	Jan Wohland	ETH Zürich	Switzerland
14209	34	19	34	25	Wind potential estimated bottom-up violates the principle of conservation of energy (de Castro et al 2011; Miller et al 2011). Moreover, the massive installation of windmills has been showed that could change the local climate change (Miller and Keith 2018). So please include these considerations. Miller, L.M., Keith, D.W., 2018. Climatic Impacts of Wind Power. Joule 2, 2618–2632. https://doi.org/10.1016/j.joule.2018.09.009 de Castro, C., Mediavilla, M., Miguel, L.J., Frechoso, F., 2011. Global wind power potential: Physical and technological limits. Energy Policy 39, 6677–6682. https://doi.org/10.1016/j.enpol.2011.06.027 Miller, L., Gans, F., Kleidon, A., 2011. Estimating maximum global land surface wind power extractability and associated climatic consequences. Earth Syst. Dynam 2, 1–12.	Partially taken into account. Effects of energy production on climate are considered in BOX XX.	Iñigo Capellán-Pérez	University of Valladolid	Spain
14477	34	19	34	33	I find that too many numbers are provided for similar elements, which confuses rather than helps the reader get the main outcome. Consider streamlining.	Accepted – text revised	Jean-Sébastien Landry	Environment and Climate Change Canada	Canada
8879	34	19	36	28	Same remark as above for solar energy : Does the costs given in $/kWh or $/kW include the back end costs i.e. deconstruction, recycling or final disposal and storage of cells, masts and blades, return to the grass of all the land occupied, including specific access roads, removal of cocrete base blocks, etc?	Accepted. The term will be defined before it is used for all technologies.	Michel SIMON	Vice Président SFENRAL	France
43321	34	20	34	25	It should be mentioned that a wind energy production of the order 1% of 1 PW = 10 TW (or even higher in the future) on a relative small area seen globally may lead to local/regional adverse effect on the wind climatology of the specific area.	Partially taken into account. Effects of energy production on climate are considered in BOX XX.	Aksel Walløe Walloe Hansen	Niels Bohr Intsitute, Uni. of Copenhagen	Denmark
28873	34	25	34	27	Figure 6.15. the legend for wind power density is very small	Editorial	Marissa Malahayati	National Institute for Environmental Studies	Japan
19849	34	26	34	26	Figure legend is not readable.	Editorial	Ghulam Rasul Athar	Pakistan Atomic Energy Commission	Pakistan
43323	34	26	34	26	the details of the figure are difficult to extract	Editorial	Aksel Walløe Walloe Hansen	Niels Bohr Intsitute, Uni. of Copenhagen	Denmark

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2149	34	27			the legend is really small	Editorial	Amy Townsend-Small	University of Cincinnati	United States of America
19621	34	27			Figure 6.15. unable to understand the meaning of the clour, legend is too small	Editorial	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	China
14475	34	29	34	33	Either different values are given for the same element, either the differences between elements are not clear enough.	Accepted – text revised	Jean-Sébastien Landry	Environment and Climate Change Canada	Canada
25069	34	31	34	31	Delete "(Rohrig et al. 2019)"	Editorial	Eleni Kaditi	Organization of the Petroleum Exporting Countries (OPEC)	Austria
45439	34				It will be good to understand how the 'weighted average' is calculated for installed costs, capacity factors and LCOE	Could change once table is in place.	Girija Parthasarathy	Thermo King	United States of America
41989	35	6			(Rohrig et al. 2019) is cited twice	Editorial	Francisco Javier Hurtado Albir	European Patent Office	Germany
44777	35	10	35	12	”The average capacity factors for newly commissioned onshore wind farms in 2018 in Denmark, Germany, Sweden and the United States were 40% to 129% higher than onshore wind farms commissioned in 1984.” While interesting, important and impressive, it is difficult to assess the increase without knowing what the capacity factor was in 1984.	Needs revision once updated statistics exist	Daniel Westlén	Liberal party Swedish parliament	Sweden
9045	35	10	35	13	The reported numbers here can be heavily affected from inter-annual wind resource variability. Comparing results based on ERA-interim and MERRA2, we reported that the year-to-year variability of wind energy generation in Germany is up to 50% based on our calculations and up to 30% based on renewables.ninja (see Fig. 3 in Wohland, 2018). In other words, the year-to-year variability is of the same order of magnitude as the changes reported here. If the reported capacity factor are corrected for the fluctuations in resource availability, I suggest that you add this information. If they aren’t, I suggest a few words of caution regarding the exact values. Reference Wohland, J., Reyers, M., Märker, C. & Witthaut, D. Natural wind variability triggered drop in German redispatch volume and costs from 2015 to 2016. PLoS ONE 13, e0190707 (2018).	Needs revision once updated statistics exist	Jan Wohland	ETH Zürich	Switzerland
6359	35	15	35	18	please make clarify what ‘control functions’ the text refers to. In particular it is unclear what ‘grid-side dynamic control capabilities’ means.	Accepted – text revised	Sciacovelli Adriano	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
16979	35	19	35	33	The unit of economic indicator (weighted-average installed costs) should be consistent. So it is better to express as USD xxx/kW or xxx USD/kW so as to avoid misleading.	Noted	Qing YANG	Harvard University	China
24335	35	19	35	33	Does this cost takes the grid adaptation into account ?	Taken into account. Information added to the text.	Alan BURLOT	Commissariat à l'énergie atomique et aux énergies alternatives	France
45437	35				Excellent information on capacity factor increase	Noted	Girija Parthasarathy	Thermo King	United States of America
28875	36	1	36	1	Figure 6.16. The figure is not clear, and what is the unit of y-axis of capacity factor?	Editorial, the unit of CF is % clearly labeled in the figure.	Marissa Malahayati	National Institute for Environmental Studies	Japan
14479	36	4	36	28	Most of this information could be conveyed more efficiently in a new table rather than through text.	Accepted. The text and figure have been revised	Jean-Sébastien Landry	Environment and Climate Change Canada	Canada
43561	36	4	36	28	Discussion of LCOE completely disregards the issue of dependancy of said LCOE on certain support mechanisms for wind power. These include in particular dispatch priority, often combined with full payments for any possible curtailment, and being exempted from any ancillary services, as well as preferences in grid access. Those measures will have to be gradually lifted, if role of wind power is to increase in the systems which are already "wind-heavy". It may be quite difficult to quantify the impact at this point of time, but it should be at least mentioned, that increasing role of wind power will also require increase of certain cost factors (risk of not selling power, necessity to install frequency control measures, necessity to run at reduced loads to provide output reserves).	Taken into account. The chapter focuses extensively on the incorporation on variable renewable sources into electricity grids, including sections on integration and a box on 100% renewable energy and electricity systems.	Adam Blazowski	FOTA4Climate.org	Poland
31429	36	14	36	28	You may argue more on the full-load hours of power plants (which influences significantly their profitability) and more on the curtailment of RES (e.g. in Germany and China).	Noted	Patrick Jochem	German Aerospace Center (DLR)	Germany
46085	36	14	36	28	there should be info on price for tenders for large wind projects, https://www.windpowermonthly.com/tender-watch	Rejected - outside the scope of the section. Many statistics exists, not all can be included.	Neven Duic	University of Zagreb	Croatia

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17155	36	14			in the discussion of moving to floating offshore wind farms further offshore; it would be useful to include discussion of the challenges that might bring to energy transport by electrons. The economics of far offshore ORE farms may favour other energy vectors, such as ammonia and hydrogen and so there is a link to the later section that discusses the energy network.	Taken into account. The power-to-X is included in section XX.XX	Deborah Greaves	University of Plymouth	United Kingdom (of Great Britain and Northern Ireland)
34685	36	18	36	18	missing comma in the number 5,400k/W	Editorial	Jordi Solé-Ollé	Spanish National Research Council (CSIC)	Spain
18691	36	21	36	21	Watson et al 2019 - reference is not found in reference section	editorial	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
34687	36	21	36	21	Reference not found in the references list.	editorial	Jordi Solé-Ollé	Spanish National Research Council (CSIC)	Spain
43847	36	29	37	4	include environmental/ecological impacts (+/-) for offshore wind developments as well	Accepted – text revised	Hans Poertner and Elvira Poloczanska	Alfred-Wegener-Institut	Germany
19851	36		36		Needs to enhance the quality of Figure	Editorial	Ghulam Rasul Athar	Pakistan Atomic Energy Commission	Pakistan
34817	36		36		Figure 6.16 Global weighted average total installed costs, capacity factors and LCOE for onshore wind requires editing. The graphical illustrations is highly obscurred. It should be redrawn.	Editorial - all figures will be redrawn	Onema Adojoh	Missouri University of Science and Technology, Rolla, USA	United States of America
316	37	1	37	4	Environmental impacts assessment of wind energy projects are more and more rigoruous. In several systems, wind turbine shut on demands are practised to avoid birds collisons during mirgratory seasons.	Accepted – text revised	El Mostafa Jamea	MENA Renewables and Sustainability - MENARES	Morocco
14481	37	5	37	5	"[C]an cause noise and aesthetic pollution". The second element is a judgment value - some people may find (I do) that wind turbines actually make some landscapes look better. Suggest rewording to something like "can cause noise and be perceived by some people as a source of visual pollution".	Accepted – text revised	Jean-Sébastien Landry	Environment and Climate Change Canada	Canada
34159	37	5	37	30	More specifically on offshore wind turbines acceptance issues do still exist, notably with the fishing industry https://www.tandfonline.com/doi/abs/10.1080/13668790500237013 [suggestion ENSEEIHT INP]	Accepted – text revised	Antoine BONDUELLE	Climate Action Network France	France
34193	37	5	37	30	More specifically on offshore wind turbines there are real acceptance challenges with the fishing industry https://www.tandfonline.com/doi/abs/10.1080/13668790500237013 [suggestion ENSEEIHT INP]	Accepted – text revised	Antoine BONDUELLE	Climate Action Network France	France
39213	37	5			Implications of socio-cultural aspects on wind power resource availability are worth mentioning. For example, the effect of restrictions on visibility of large wind farms n the proximity of urban areas has been estimated for the global energy potential of onshore wind (see Silva Herran et al., Energy Policy, 2016).	Wrong section - should be wind	Diego Silva Herran	National Institute for Environmental Studies	Japan
19853	37	12	37	12	Need to change 'wind' to 'wind turbine'.	Editorial	Ghulam Rasul Athar	Pakistan Atomic Energy Commission	Pakistan
10899	37	13	37	16	It should also be noted in this paragraph that, contrary to common perceptions about acceptance issues only occurring for onshore wind, offshore renewable energy developments are not immune to issues with local acceptance. Relevant work to support this includes: de Groot, J. and Bailey, I. (2016) What drives attitudes towards offshore renewable energy in island communities? International Journal of Marine Energy, 13: 80-95; Bailey, I., West, J. and Whitehead, I. (2011) Out of sight but not out of mind? Public perceptions of wave energy and the Cornish Wave Hub, Journal of Environmental Policy and Planning 13, 139-158. Importantly, these issues are not restricted to offshore wind and are also pertinent to wave and other osshore technologies. Howes and Devine-Wright also ocnducted research in this area (2010), as did Haggett (2008)	Acepted - text revised	Ian Bailey	University of Plymouth	United Kingdom (of Great Britain and Northern Ireland)
15059	37	19	37	20	"wind energy must still compete with conventional sources, on a cost basis" - the problem is not the "cost basis", but the huge external cost of fossil and nuclear energy which is neglected in calculations.	need help from policy expert.	Béla Munkácsy	ELTE University	Hungary
15061	37	21	37	22	"The problem of energy storage is the last, but an important link to fully integrate weather-dependent renewables into society." - energy storage is crutial for base-load power production as well, which means that it is not a special problem of weather-dependent technologies, that the sentence suggests.	Accepted - text revised	Béla Munkácsy	ELTE University	Hungary
18693	37	21	37	22	The problem of energy storage is the last, but an important link to fully integrate weather-dependent renewables into society.' - suggest this is more than an 'important link' - it is a critical link over different timescales. Suggest 'The increased use of energy storage over different timescales (sub-second frequency to within day to seasonal) is a critical link to integrate greater and greater levels of weather-dependent renewables into energy systems.'	Accepted - text revised	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)

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4133	37	23	37	30	This paragraph is helpful. I would add that experince in Canada has shown the same thing (re: lines 29-30). You should add work from: Walker, C., & Baxter, J. (2017). Procedural justice in Canadian wind energy development: a comparison of community-based and technocratic siting processes. Energy research & social science, 29, 160-169. I would also go durther in noting that a lack of local investors (but also local benefits more broadly) AND local control, especially when community-based development is proposed/advertised, is what is shaping opposition/low levels of support. You should probably also mention how such opposition movements are threatening our ability to create policy that canb withstand elections (see examples from the UK wind energy industry and Canada; Walker, C., Stephenson, L., & Baxter, J. (2018). “His main platform is ‘stop the turbines’”: Political discourse, partisanship and local responses to wind energy in Canada. Energy policy, 123, 670-681.)	Taken into Account. The paragraph has been removed, so this comment is no longer relevant.	Chad Walker	University of Exeter	United Kingdom (of Great Britain and Northern Ireland)
39715	37	31	40	23	The section on bioelectricity ignores the options of (even carbon-negative) biomethane and ist high-efficient conversion in solid-oxide fuel cells (SOFC) and cogeneration (combined heat, cooling & power), as well as in high efficient combined-vycle cogeneration plants replacing coal, oil and natural gas. Furthermore, biomeethane offers longer-term storage options far less costly than batteries, Power-to-Gas or traditional storage, as existing natural gas storage can be used. There are various recent references for these aspects - if need be, those can be made available.	Wrong section - should be bioenergy	Uwe Fritsche	IINAS	Germany
40145	37	34	39	23	In general hydro power must play an very imporant role in the future, because it is a renewable source that can stabalice the grid and can compensate the fluctuation of wind power and PV. With pump-storage-power plants it is possible to store energy, which will be also very important in future.	Noted	Armin Winkler	University of Applied Sciences Upper Austria/ Global Hydro Energy GmbH	Austria
19855	37	35	37	35	Word 'hydro' may be added after available, ‘available hydro potential’.	Accepted, text revised	Ghulam Rasul Athar	Pakistan Atomic Energy Commission	Pakistan
39281	37	35	37	35	Is geophysical really the good term ? The paragraph talks more about georessources than geophysics.	yes, thank you	Bruno Gavazzi	UMR7516 Institut de Physique du Globe de Strasbourg (CNRS/Université de Strasbourg	France
19857	37	35	37	46	Comparison of hydro potential with its share in energy production is confusing. For example, in Lines 38-39 of page 6.37, it has been stated that ‘, … while the present energy production by hydropower plants is just 3% of the annually required energy’. According to International Energy Agency database, hydropower generated 4,197 TWh electricity in 2017 that was equivalent to 351 MTOE. In total primary energy supply (14, 035 MTOE) share of hydropower was 2.5%. However, in BP Statistical Review of World Energy (68th Edition), hydropower generation, in 2017, was 4,066 TWh equivalent to 920 MTOE that was 6.8% of total primary energy - 13,475 MTOE. It can be observed that electricity generation data in both cases is almost same (3% difference), but differences in equivalent primary energy and share in energy are large. These differences are due to assumed efficiency for conversion of hydroelectricity to thermal equivalence. Hydro is an electricity generation source and comparison of its potential with its share in electricity mix is meaningful. If we look into both databases (IEA and BP) share of hydroelectricity in electricity generation mix was 16% in 2017.	Accepted. Text revised	Ghulam Rasul Athar	Pakistan Atomic Energy Commission	Pakistan
39671	37	35	37	46	The SRREN report (IPCC 2011) defined the technical potential of hydropower at 50-52 EJ/yr. This paragraph presents a range of newer studies with much larger estimates, and a larger span, with differing wording of what the potentials really mean. If the "theoretical available potential" is in fact relevant, an explanation to how this relates to the technical potential assessed in previous estimates, and why it is different, is needed.	Rejected: beyond the mandate of the report.	Simon Davidsson Kurland	Chalmers University of Technology	Sweden
9537	37	38	37	39	Clarify "% of energy": percent of total primary energy, or % of total electricity produced?	Accepted, text revised	Tom Kram	PBL (Fellow)	Netherlands
19623	37	38	37	39	"energy production by hydropower plants is just 3% of the annually required energy." the convert factor of hydropower In IEA statistics is 100%, this may underestimate the contribution of hydropower in energy supply. So. It is better to use "consumed" than "required" here.	Accepted. Text revised	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	China
14483	37	38	37	46	Values do not fit together: "52 PWh/year is equal to 33% of the global annual required energy" versus "10,000 TWh/year [which] represents approximately 40% of the total energy generated during 2017".	Accepted. Text revised	Jean-Sébastien Landry	Environment and Climate Change Canada	Canada
14485	37	39	37	44	Values about the total potential from hydropower do not fit together, even if they all refer to Zhou et al. (2015).	Accepted. Text revised	Jean-Sébastien Landry	Environment and Climate Change Canada	Canada
15145	37	42	37	42	Highly recommend looking at the world's hydropower potential not only from the continent's perspective, but also from the countries perspective as well. Thus enlarge this line: 'The greatest contributor to the hydropower potential is Asia (48%), followed by S. America (19%)' to countries having the greatest hydropower potential, thus mentioning China, Russia, Canada, DRC, US, etc., at least top-10.	Rejected: beyond the mandate of the report.	Aleksandr Kraevoy	UC RUSAL	Russian Federation
15063	37	44	37	44	"2016b).According" - missing space	Editorial	Béla Munkácsy	ELTE University	Hungary

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13847	37	45	37	45	"10 PWh" instead of "10 000 TWh" would make units used in that paragraph more consistent	Accepted. Text revised	Alexandre Bizeul	International Energy Agency	France
15065	37	45	37	45	"TWh / year" - unnecessary space	editorial	Béla Munkácsy	ELTE University	Hungary
18695	37	45	37	46	This represents approximately 40% of the total energy generated during 2017' - is this primary energy or electricity generated?	Accepted. Text revised	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
13849	37	45	67	46	This not 40% of energy generated but electricity generated (source IEA World Energy Balances 2019, https://www.iea.org/data-and-statistics?country=WORLD&fuel=Energy%20supply&indicator=Electricity%20generation%20by%20source) . Or it is 7% of 2017 total primary energy supply.	Accepted. Text revised	Alexandre Bizeul	International Energy Agency	France
19625	37	46			"represents approximately 40% of the total energy generated during 2017" total electricity generation? total energy generated during 2017 is much larger, 10000TWh is less than 10% of it.	Rejected: acording to IEA, 2018, the values are correct.	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	China
20747	38	2			Figure 6.17. what is the spatial unit ?	Noted. The paper does not specify the spatial resolution of the map. But including that info is not critical for the narrative of the chapter.	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	China
6361	38	3	38	4	Please rephrase to more precisely. It is important to specify that Hydroelectric power comes from the conversion of potential energy (gravitational energy) possessed by water into kinetic energy and finally into electrical energy through turbomachines coupled to electric generators.	Taken into account - combined with another comment	Sciacovelli Adriano	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
19859	38	3	38	4	Water Head (potential energy) is also important. Currently most of the hydroelectricity is produced using water head (height). The sentence 'Hydroelectric power comes from water in motion, which turns turbines that convert the water kinetic energy into electricity via a turbine shaft and a generator' may be changed as 'Hydroelectric power comes from water in motion, which turns turbines that convert the water's kinetic and potential energies into electricity via a turbine shaft and a generator'	Taken into account - combined with another comment	Ghulam Rasul Athar	Pakistan Atomic Energy Commission	Pakistan
39673	38	3	38	21	Hydropower may depend on kinetic energy / water in motion, but explain the relation to potential energy. More referencers needed.	Accepted. Text revised	Simon Davidsson Kurland	Chalmers University of Technology	Sweden
22917	38	3	39	20	In this part it remains to mention that, hydropower projects can be classified, in terms of installed capacity, into large, medium and small or micro types, and small hydro stations are usually more practical for construction and operation in rural areas with less investment and environmental impacts. In addition, some good examples or unsuccessful cases can be cited to help paint a more complete picture of world-wide hydropower development.	Taken into account - covered in Section 6.5	Xiusheng Zhao	Tsinghua University	China
40135	38	5	38	6	I would rewrite the sentence: "Hydropwer plants can be located on rivers, streams and canals and mostly dams are needed for reliable water supply". --> dams are not compulsaory needed	Accepted. Text revised	Armin Winkler	University of Applied Sciences Upper Austria/ Global Hydro Energy GmbH	Austria
5895	38	7			EROI (0r ERoEI) is not addressed sufficiently in this chapter. It deserves an entire section for all energy technologies as covered widely (and controversially) in recent literature. Eg see http://www.soest.hawaii.edu/GG/FACULTY/ITO/GG410/EROI_Future_Energy_Sources/Murphy_EROI_AnNYAcSci10.pdf and https://www.sciencedirect.com/science/article/pii/S0301421516301379 and https://www.sciencedirect.com/science/article/pii/S0301421516307066 Also LCOE comparisons across energy technologies would be useful (as in the summary figure in AR5). Overall however, this section 6.4 is another "Energy 101" and too descriptive. So could be cut considerably.	Taken into Account. EROI is addressed variously throughout the chapter, although there is no specific section on it. For example, the fossil section explicitly discuss EROI, and the wind section disucsses the carbon payoff time for wind turbines, which is roughly correlated with EROI. We will revisit this issues following comments on the SOD.	Ralph Sims	Massey University	New Zealand
5893	38	13			Micro-hydro can be as low as 1kW - so not just at MW scales	Accepted: text revised	Ralph Sims	Massey University	New Zealand
31807	38	14	38	15	However, there are challenges due to silting and desilting is an expensive operation. Should mention that.	Rejected: The chapter does not talk over all the many challenges of hydropower operation	Ashok Sreenivas	Prayas (Energy Group)	India
40137	38	14	38	15	The peak efficiency of most hydroelectric power plants is greater than > 90%; the highest of all genration technologies.	Rejected: 85% is efficiency estimation considering several sources.	Armin Winkler	University of Applied Sciences Upper Austria/ Global Hydro Energy GmbH	Austria

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27919	38	17	38	21	The IPCC states, "Hydroelectric technology has the added advantage to allow high levels of penetration of intermittent renewable energy such as solar and wind energy to be achieved without compromising the reliability and continuity of the electricity grid, since it has the capacity to deal with the random variations in the power of intermittent power plants and it can be used as a peak load to reduce the costs derived from the dispatch of the most expensive plants." For this conclusion, please cite Jacobson, M.Z., M.A. Delucchi, M.A. Cameron, and B.A. Frew, A low-cost solution to the grid reliability problem with 100% penetration of intermittent wind, water, and solar for all purposes, Proc. Nat. Acad. Sci., 112 (49), 15,060-15,065 doi: 10.1073/pnas.1510028112, 2015. This paper showed that, at high penetrations of wind and solar, increasing the peak discharge rate of hydro (by adding turbines) without changing the annual water flow rate of a reservoir could enable matching continuous demand with intermittent supply at low cost.	Accepted. Text revised	Mark Jacobson	Stanford University	United States of America
13851	38	22	38	23	One economic aspect might be underlined : this is closely linked to the geophysical aspect as there are great disparities in hydroelectric cost depending on the location, higher than other sources.	Taken into account - combined with another comment	Alexandre Bizeul	International Energy Agency	France
20749	38	22	38	33	Costs of hydropower plant are not discribed in quantitative term as for solar and wind	Noted.	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	China
31809	38	22	38	33	The paragraph on economic aspects of hydro power is strangely bereft of numbers. The experience, at least in India, is that they are extremely capital intensive and suffer from huge delays (further increasing cost) as a result of which it does not have consumers. A good example is the set of hydro projects on Teesta in Sikkim and similarly the various projects in Arunachal Pradesh.	Taken into account - combined with another comment	Ashok Sreenivas	Prayas (Energy Group)	India
39675	38	22	38	33	Explain how the cost has evolved over time and if it varies with locations, with references.	Noted.	Simon Davidsson Kurland	Chalmers University of Technology	Sweden
15067	38	30	38	30	m3 - superscript	editorial	Béla Munkácsy	ELTE University	Hungary
31431	38	33	38	33	What is O&M?	editorial -- The cost of operation and maintenance, but that sentence as omitted	Patrick Jochem	German Aerospace Center (DLR)	Germany
15069	38	34	38	34	"Although hydroelectric power plants have many advantages over other energy sources, they also have potentially serious environmental and societal impacts" - it would be important to indicate that smaller size applications have much smaller impacts	Taken into account - we added 'may' to acknowledge that not all dams cause such large impacts.	Béla Munkácsy	ELTE University	Hungary
9539	38	34	39	4	This paragraph is too incomplete ans sketchy to be a credible attempt. Serious environmental issues such as methane from flooded land, loss of land-based ecosystems to reservoirs, silting and loss of fertile deposits downstream, loss of culture and heritage, and many other downsides are associated with hydropower that warrant at least mentioning.	Taken into account - these points are already mentioned. We have added the point about loss of culture and heritage	Tom Kram	PBL (Fellow)	Netherlands
11999	38	34	39	4	In my view it is not so interesting to make such broad assessments on hydro power since the impacts are very site specific (e.g. topografi and existing population etc.), depend on how a power plant is developed and there are large differences between the regions. E.g. a high moutain water reservoir will have little previous vegetation and therefor low emissions compared to a reservoir in the tropics. The emissions are highest in the first period of the plants life time. I therefore think that it would be useful to underline the need for good planing, site selection and regulatory frameworks.	Accepted: text revised	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
40139	38	34	39	4	The described disadvantages are not a problem for all hydropower plants. For example there are a lot ways to make turbines and power plants fish friendly, there are fish lifts, etc. There is also a big difference between large hydro and small hydro power plants. Small hydro power plants often have only a very small influence on the environment.	Taken into account - combined with another comment	Armin Winkler	University of Applied Sciences Upper Austria/ Global Hydro Energy GmbH	Austria
1655	38	34	39	13	Include references on the ecological consequences of HEP dams. For example: McCartney, M., 2009. Living with dams: managing the environmental impacts. Water Policy, 11, pp.121-139. https://doi.org/10.2166/wp.2009.108	Accepted: text revised	Jenkins Rhosanna	University of East Anglia	United Kingdom (of Great Britain and Northern Ireland)
37997	38	35	38	35	The words 'they also have potentially serious environemntal and societal impacts' should be replaced with more objective / less emotive phrasing. For example 'there are potential environemtal and societal risks that need to be managed carefully'	Accepted: text revised	Atle Harby	SINTEF Energy Research	Norway
37999	39	1	39	1	The words 'Below the hydropower dam, there are considerable alterations…' should be replaced with more objective / less emotive phrasing. For example 'Below the hydropower dam, there CAN BE considerable ….'	Accepted: text revised	Atle Harby	SINTEF Energy Research	Norway
38001	39	2	39	4	The wording of this sentence could be improved to read 'From a societal perspective, construction of power plants may lead to POSITIVE or NEGATIVE changes to naviation, outdoor recreation and fishery…	Accepted: text revised, but not exactly as suggested by the reviewer	Atle Harby	SINTEF Energy Research	Norway
41991	39	2			"water quality and temperature, although to methane emmissions"	the comment belongs to section 6.4.2.3	Francisco Javier Hurtado Albir	European Patent Office	Germany

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6031	39	4	39	4	Consider to include flooding risk impacts to downstream communities i.e. dam break or release of excess water (if combined with flood mitigation). This issue is of particular concern in developing countries whereby the framework for emergency response in the event of such incidents are not well developed	Rejected: The chapter does not talk over all the many challenges of hydropower operation	SAIK PENG, CASEY NGO	R-SYNC TECHNICAL RESOURCES SDN. BHD.	Malaysia
6033	39	4	39	4	Consider including the societal impacts of displacement of communities especially of aboriginal nature, loss historical / burial sites	Taken into account: ressetlement is already mentioned in the text.	SAIK PENG, CASEY NGO	R-SYNC TECHNICAL RESOURCES SDN. BHD.	Malaysia
38013	39	4	39	4	I suggest to replace "In addition, management of competing water uses is needed." with "In addition, hydropower provides many other services than electricity and energy storage, like flood control, drought management, water supply, navigation, aquaculture, recreation and tourism. These services may be in competition with hydropower, but most of the time they are additonal services"	Rejected: restrictions in the size of the chapter requires a consise way of expression. But to avoid singling out one use, we decided to remove the sentence	Atle Harby	SINTEF Energy Research	Norway
41993	39	4			At the end of the sentence, include "(interaction with drinkable water supply and with irrigation)"	the comment belongs to section 6.4.2.3	Francisco Javier Hurtado Albir	European Patent Office	Germany
6165	39	5	39	6	The text says that hydropower does not emit any kind of GHG. But, as shown in some studies (and indeed mentioned in the next paragraph), the reservoirs may emit methane from the decomposition of organic matter. This should be mentioned. I also miss a discussion of the societal impact associated with the displacement of population required when areas are flooded.	Taken into account: both emission of GHG and displacement are mentioned in section.	Linares Pedro	Universidad Pontificia Comillas	Spain
31811	39	5	39	6	While hydro may not generate GHG emissions during generation, they do result in methane and other emissions due to submergence of forests and so on.	Taken into account: emission of GHG is mentioned in the section.	Ashok Sreenivas	Prayas (Energy Group)	India
44779	39	5	39	6	”Hydroelectric power generation is a technology that uses the potential and kinetic energy of water, so it does not emit any kind of greenhouse gases during the process of generating electricity,” As this is an IPCC report it would be odd not to mention the life cycle emissions and only refer to the situation during the electricity production itself. The dam construction adds to climate emissions, and depending on siting and climate there may be substantial climate impact due to methane emissions from biological processes. There must surely be scientific literature on this that should be considered. I see no such assessments for the other energy sources either, so it may be outside of the scope for AR6, but if so then this sentence is even more strange. If you discuss the climate impact from different options then the life cycle perspective would be relevant.	Taken into account: emission of GHG is mentioned in the section.	Daniel Westlén	Liberal party Swedish parliament	Sweden
39677	39	5	39	9	Hydropower dams can cause substantial emissions of methane. Although it is uncertain how large these emissions really are, there are many studies looking into this, which should be mentioned. See eg. Räsänen, T.A., Varis, O., Scherer, L., Kummu, M., 2018. Greenhouse gas emissions of hydropower in the Mekong River Basin. Environ. Res. Lett. 13, 034030. https://doi.org/10.1088/1748-9326/aaa817	Taken into account: emission of GHG is mentioned in the section.	Simon Davidsson Kurland	Chalmers University of Technology	Sweden
9541	39	6	39	6	Incorrectly and biased statement on GHGs: large volumes of materials (e.g. concrete) imply 'embedded' GHG emissions can be substantial. And so can the aforementioned, though site-specific, issue of methane emissions from reservoirs	Taken into account: emission of GHG is mentioned in the section. Accepted: text has been modified to include GHG emissions from concrete	Tom Kram	PBL (Fellow)	Netherlands
38015	39	10	39	11	I find the sentence "Because the water potential can be located in places with human settlements and hydroelectric plants are usually large projects, they do not have a social acceptance like other technologies." flaw and very unprecise. First of all, the vast majority of hydropower plants are below 10MW, or even below 1MW. Hence it is not correct to say that hydroelectric plants are usually large projects. However, the 5 largest power plants of any category in the world, are hydropower plants. It's mainly the dam and reservoir who does not get social acceptance. However, only 30 per cent of the large dams in the world are equipped with hydropower, and many of them are multipurpose. I suggest that more qualified and informed authors should write about hydropower, the text seem to be biased and incorrect and not based on scientific evidence that is a pre-requisit for IPCC standards	Accepted: text revised	Atle Harby	SINTEF Energy Research	Norway
4135	39	10	39	13	It is important to note here that opposition to large-scale hydro development may be espcially prominent in Indigenous contexts, where history and culture (e.g. modern-day fishing grounds) are erased and local health threats are introduced. This kind of development has been called a form of [low[carbon colonialism in South American (Finley-Brook, M., & Thomas, C. (2011). Renewable energy and human rights violations: Illustrative cases from indigenous territories in Panama. Annals of the Association of American Geographers, 101(4), 863-872) and Canadian (Walker, C., Alexander, A., Doucette, M. B., Lewis, D., Neufeld, H. T., Martin, D., ... & Castleden, H. (2019). Are the pens working for justice? News media coverage of renewable energy involving Indigenous Peoples in Canada. Energy Research & Social Science, 57, 101230) contexts.	Taken into account: resettlement and loss of culture and heritage are already mentioned	Chad Walker	University of Exeter	United Kingdom (of Great Britain and Northern Ireland)
24337	39	10	39	13	needs a reference and maybe a few details	Noted	Alan BURLOT	Commissariat à l'énergie atomique et aux énergies alternatives	France
40141	39	10	39	13	There are much more small and medium power plants than large project with lower impact on environment and with high social acceptance.	Noted	Armin Winkler	University of Applied Sciences Upper Austria/ Global Hydro Energy GmbH	Austria

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37973	39	12	39	13	The sentence "because large areas of land are flooded, the organic matter at the bottom of the dam can generate significant greenhouse gas emissions" is far from up-to-date with respect to scientific knowledge. The issue of greenhouse gas flux from hydropower reservoir is a complex issue. This must be explained better, as the organic matter at the bottom of the dam is not the main source of GHG emissions in most cases. Please see the chapter 7 on "Flooded land" in Volume 4 of the "2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories" and a large number of literature. Please see Prairie, Y.T., 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. 2017. Greenhouse Gas Emissions from Freshwater Reservoirs: What Does the Atmosphere See? Ecosystems, DOI: 10.1007/s10021-017-0198-9. CO2 emissions from reservoirs are mainly displaced emissions that would have occured elsewhere, except for some emissions from the mobilisation of the soil. However, the main issue is often whether there has been generated methane in stead of CO2. This may happen in anoxic conditions when autochtonous and alochtonous carbon are decomposed. Then, it's a question whether the methan find a pathway to the atmosphere or not, either through ebullition from the reservoir, at the air-water interface in the reservoir or downstream the turbines (degassing). Methane can also be oxidised back to CO2 and hence have no additional impact from the natural cycling. In addition, carbon and nutrient loading from other anthropogenic sources can also lead to GHG emissions, and there is also a chance of sequestering carbon and creating a flux from the air to the water (Chanudet, V., Descloux, S, Harby, A., Sundt, H., Hansen, B.H., Brakstad, O.G., Guerin, F. 2011. Annual gross CO2 and CH4 emissions and carbon budget of the Nam Ngum and Nam Leuk sub-tropical Reservoirs in Lao PDR. Science of the Total Environment, doi: 10.1016/j.scitotenv.2011.09.018)	Accepted: text revised	Atle Harby	SINTEF Energy Research	Norway
6035	39	13	39	13	Consider to elaborate more on the impacts of air quality during development and long term operation of the hydropower dam. Reservoir flooding is usually conducted without removal of vegetation, which will result in generation of greenhouse gases due to biomass degradation. This aspect is usually not highlighted in the overall lifecycle analysis of hydropower projects, leading to the impression that hydropower has 'zero emissions' impact.	Taken into account: the aspect about GHG emissions from hydrpower dams is mentioned	SAIK PENG, CASEY NGO	R-SYNC TECHNICAL RESOURCES SDN. BHD.	Malaysia
14487	39	13	39	13	Add some text to mention the very large differences in GHG emissions from hydro dams between tropical and non-tropical areas.	Rejected. We don't have the space to expand on the GHH emission aspect	Jean-Sébastien Landry	Environment and Climate Change Canada	Canada
15071	39	14	39	14	"longer than other technologies" - longer than most of the renewable technologies	Accepted: text revised	Béla Munkácsy	ELTE University	Hungary
12001	39	14	39	15	About the construction time what do you compare with? Nuclear power (also long construction time) or wind power? Also why does a longer contruction time give larger uncertaity related to completion. I would guess that this is even more relevant to e.g. nuclear power and thet the unceratinty is linked to the how well planed the project is and the inclusion of stakeholders in the decision phase and good governace in general.	Accepted: text revised	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
40143	39	14	39	15	I would delete this sentence, because hydro power projects can be realised within months.	Rejected: the text express a general view	Armin Winkler	University of Applied Sciences Upper Austria/ Global Hydro Energy GmbH	Austria
31813	39	15	39	15	There is also greater uncertainty regarding costs since it is extremely site specific. This makes planning, financing etc. very difficult.	Taken into account: we make the point about the uncertainty in cost and being site specific in the text	Ashok Sreenivas	Prayas (Energy Group)	India
1539	39	19	39	20	The risk for conflicts from climate change mentioned here relates to hydropower and water shortage. The growing risk for conflicts, a threat to human security due to climate change, is actually an issue on a global scale. It spreads out to many countries (particularly developing countries) and technologies. In the Netherlands there is an initiative to increase attention and create solutions for these risks, receiving high-level attention and involvement from the government, the military and research organisations. This is the Planetary Security Initiative platform and project: https://www.planetarysecurityinitiative.org/. An example of literature on this topic, is this which has identified important drivers for conflicts in countries worldwide, namely the level of public governance, poverty and economical inequality: H. Visser (2019), Planetary security: in search of drivers of violence and conflict. Part II: Inferences through Machine Learning. PBL Netherlands Environmental Assessment Agency, The Hague.	Noted.	Paul Vethman	PBL Netherlands Environmental Assessment Agency	Netherlands
38005	39	19	39	20	Is this sentence sufficiently balanced against prior sentecnes ie. benefits on the whole outweigh such risks etc?	Noted.	Atle Harby	SINTEF Energy Research	Norway
42361	39	24	41	6	uclear receives negative reviews due to various reasons. At present, it is the most expensive energy generation technology in addition to the social, institutional and political challenges that it faces, as also discussed in this document. The document tries to present SMRs as future technology but gave little information on how it solves some of the existing challenges. I think, it is better to clarify the present challenges and what needs to be address for it to remain in the market.	Rejected. The comment is ok, but the text is not misleading neither nor giving false hopes on SMRs. The challenges are common for nuclear, should it be small size or big size. For SMRs a lot will depend on the first of a kind.	Solomon Asfaw	LUT University	Finland

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15097	39	24	42	6	the whole section of "Nuclear Energy" has an unilateral technology-based approach with tendentious selection of information. It is not mentioned that: a) according to independent researchers, nuclear power does have a relatively big and growing carbon footprint because of using low-grade uranium ore (Barnham, K. 2015: https://theecologist.org/2015/feb/05/false-solution-nuclear-power-not-low-carbon); b) Nuclear power plants take at least 20 years to plan and build - according to the IPCC, we have only 10 years to reach a complete change in every segment of economy; c) nuclear energy projects are tightly connected to corruption, see the cases in Slovakia (Mohovce) and Hungary (Paks) (https://www.energiaklub.hu/files/study/corruption_risks_paks2.pdf); d) nuclear power plants function inefficiently during droughts and heatwaves becase of their significant water consumption for cooling (see cases in Hungary, Paks) (https://www.neimagazine.com/news/newseuropes-heatwave-affects-npps-6271432); e) nuclear energy most of the cases causes energy dependence (see the damaging Russian influence in Eastern Europe); f) nuclear energy players (as Rosatom) actively act against sustainable energy developments, as wind energy and energy efficiency (in Eastern Europe)..	Rejected. The text gives a balanced view of current state of nuclear power potential and technological options. The section is on nuclear power, so yes it's technology based. A) nuclear power has 0 carbon footprint from operation and very small footprint from entire LCA (Gibon T. https://www.sciencedirect.com/science/article/pii/S2212827114004934), B) the process of planning and building all together is around 10 to 15 years, the text gives estimates for potential for mitigation from nuclear power in the medium to longer term, C) not supported by the peer-reviewed published literature, D) Climate change impacts affect all energy system (generation technologies,transmission, distribution, etc), adaptation measures will need to be considered after careful vulnerabilities assessments, the given space does not allow discussion on this topic E), F) not supported by the peer-reviewed published literature	Béla Munkácsy	ELTE University	Hungary
9543	39	24			Paragraph 6.4.2.4. presents an unbalanced and overly optimistic picture of nuclear energy. The part on FBRs fails to mention that attempts to build and oprate these have failed and lead to sizeable finabcial losses. Perceived or not, concerns over proliferation of nuclear arms and over nuclear waste are hardly mentioned, and done away with as lack of knowledge of and experience with nuclear installations.	Rejected. The claim for an unbalanced and overly optimistic treatment would need to be better substantiated. Concerns are discussed to the extent that space allows.	Tom Kram	PBL (Fellow)	Netherlands
16269	39	24			In Section 6.4.2.4 Nuclear Energy, consider adding a subsection entitled [geopolitical] and therein describe the increasing risk of nuclear arms proliferation from nuclear power use by 29 “newcomer” countries. See, for example, Goldemberg, J., 2009. Nuclear energy in developing countries. Daedalus, 138(4): 71-80. Notably missing from plans for adopting nuclear power in a widespread fashion to address climate change is a new international mechanism that would identify the most nuclear-arms-proliferation-resistant pathway and require that this pathway be followed. The current Non-Proliferation Treaty was not adopted to address climate change, and its utility is not up to the task. For example, Saudi Arabia is presently developing facilities for nuclear materials enrichment to fuel its planned new nuclear power program, and this may be a pretext for nuclear arms production. Including this information will be a service to the reader. The current treatment of nuclear arms proliferation present in the [Environmental/Ecological] subsection currently lacks sufficient detail for a reasonable reader to gain a clear assessment of the risk involved.	Rejected. Nuclear industry and the NPP market are highly regulated at both national and international levels. All countries wishing to use nuclear power should comply with all these regulations and safety standards.	Daniel Helman	College of Micronesia-FSM	Micronesia, Federated States of
39271	39	25	39	25	Is geophysical really the good term ? The paragraph talks more about georessources than geophysics.	Noted. Geophysical indicator includes, among others, geophysical resources	Bruno Gavazzi	UMR7516 Institut de Physique du Globe de Strasbourg (CNRS/Université de Strasbourg	France
35431	39	25	39	32	Equity issues have to be taken into account regarding uranium resources, since they are often located on indigenous people’s territories. According to an 2010 statement of the NGO International Physicians for the Prevention of Nuclear War, it was the case for 75% of the then current resource. https://www.ippnw.org/pdf/2011-resolution-uranium-ban.pdf	Rejected. Not supported by the peer-reviewed published literature	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France
8881	39	25	39	37	It should mentioned that the periods (130 years or 250 years) are estimated for use of uranium in current design reactors (excludind fast breeders), with open fuel cycle (no recycling or Mox use)	Noted. The text says "at current generation levels of nuclear power".	Michel SIMON	Vice Président SFENRAL	France
14489	39	26	39	27	"[O]ver 130 years of supply" - at the current level of use?	Noted.	Jean-Sébastien Landry	Environment and Climate Change Canada	Canada
15073	39	28	39	28	"USD 260 / kgU" - unnecessary spaces	Accepted. Text revised.	Béla Munkácsy	ELTE University	Hungary
31817	39	28	39	32	It may also be pertinent to point out that nuclear energy costs have generally been increasing with time, unlike many other technologies, particularly solar, wind etc.	Accepted. Text revised.	Ashok Sreenivas	Prayas (Energy Group)	India
19861	39	32	39	33	Word ‘not’ or ‘currently’ is missing in sentence ‘Furthermore, uranium is only one of the types of material that can be used to fuel nuclear reactors.’ The sentence can be modified either ‘Furthermore, uranium is not only one of the types of material that can be used to fuel nuclear reactors.’ Or ‘Furthermore, currently uranium is only one of the types of material that can be used to fuel nuclear reactors.’ As, it is stated in next sentence, Thorium, which is roughly four times as abundant in the earth’s crust as uranium, is another alternative.	Noted. The main idea though is to say that: as a result of subsequent discoveries of uranium and nuclear capacities growing at a much slower rate, an adequate and reliable supply of uranium weakened all incentives for alternaive fuels or fuel cycles.	Ghulam Rasul Athar	Pakistan Atomic Energy Commission	Pakistan
34111	39	33	39	35	No full-scale thorium-based reactor has ever been built.	Noted.	Antoine BONDUELLE	Climate Action Network France	France

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35433	39	33	39	35	No full-scale thorium-based reactor has ever been built.	Noted.	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France
32271	39	35	39	35	This is not fully exact. The (generally) low interest in thorium is mainly due to the fact that thorium is not fissionable in itself. It requires to be transformed in Uranium 233 through a neutron capture, and, then, has to be put in a reactor to initiate the process. This is long and can be costy. Only India is (or was) really interested in thorium, because of its large reserves.	Noted.	Jean-Guy Devezeaux de Lavergne	Commissariat à l'Energie Atomique et aux Energies Alternatives	France
696	39	35	39	37	The message carried by this sentence is realy not clear	Accepted. Text revised. The message is that low uranium prices and it's ample availability weaken incentives for the expansion of reprocessing (for recycling purposes)	Francois-Marie Breon	CEA	France
32273	39	36	39	37	Reprocessing the spent fuel allows to recycle both plutonium (prodiced in tehe fuel throuh neutron captures) and "unburnt" uranium. This technique allows to save roughly 20% of the initial uranium in the today's reactors. Its cost is not significantly diffrenet from the cost of the "on-through" option. https://www.oecd-nea.org/ndd/pubs/2013/7061-ebenfc.pdf	Noted.	Jean-Guy Devezeaux de Lavergne	Commissariat à l'Energie Atomique et aux Energies Alternatives	France
14491	39	38	39	38	"Nuclear energy would be practically decoupled from the resource constraint". Please tone down this statement: resource constraint would be alleviated, but would not disappear.	Accepted. Text revised	Jean-Sébastien Landry	Environment and Climate Change Canada	Canada
31815	39	38	39	39	That seems to be a very ambitious claim to make considering that the technology is still struggling to reach maturity, and costs have only been increasing.	Accepted. Text revised.	Ashok Sreenivas	Prayas (Energy Group)	India
20377	39	38	39	44	better mention also the drawbacks and challenges of FBR: https://www.tandfonline.com/doi/full/10.2968/066003007#abstract	Accepted. Text revised.	Christian Breyer	LUT University	Finland
34113	39	38	39	44	Fast-breeder reactors have serious non-proliferation issues but also societal and cost issues.	Rejected. Not supported by the peer-reviewed published literature	Antoine BONDUELLE	Climate Action Network France	France
35435	39	38	39	44	Fast-breeder reactors also face strong societal opposition.	Rejected. Not supported by the peer-reviewed published literature. The opposition or acceptance should not be in general any different from current reactor types.	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France
14493	39	39	39	39	I think the text should be "(FBR) would allow" because the text below (lines 43-44) seem to mean that FBR are not developed yet.	Noted.	Jean-Sébastien Landry	Environment and Climate Change Canada	Canada
45443	39	42			The section on nuclear energy is not a balanced view. There is no review of how radiactive waste would be handled (e.g. there are still power plants operating in the US that do not have a permanent soution for radioactive waste storage e.g. Prairie Island nuclear power plant), there is no mention of the immense environmental and health impacts of radioactive exposure. Instead it states that nuclear has the 'lowest acidification and eutrophication' amongst alternatives. Waat are these alternatives - fossil fuel plants, solar PV, wind power?	Accepted. The claim for an unbalanced treatment would need to be better substantiated. The discussion on waste is limited by space. Text is revised with regards to environmental impacts.	Girija Parthasarathy	Thermo King	United States of America
16981	39	43	40	2	The water competetion for hydropower and irrigiation is an critical problem, which should be added and clarified clearly in this part.	Rejected. Hydropower is addressed in Section 6.4.2.3	Qing YANG	Harvard University	China
14495	39	46	40	2	This listing of model names/numbers by country is of little value - I suggest deleting.	Accepted. The text is revised	Jean-Sébastien Landry	Environment and Climate Change Canada	Canada
22919	39	47	40	1	In fact, the first 4 units of AP1000 type(3G) have been already completed and put into commercial operation in China's Sanmen Nuclear Power Plant (Zhejiang Province) and Haiyan Nuclear Power Plant(Shandong Province) respectively. In addition, there are 4 EPR projects in the world, one in France, on in Finland, and two in China, the construction started earlier in Europe, but they have NOT been finished yet due to some technical problems there, China's 2 units have been successfully completed 2019 and put into commercial operation, becoming the world's first two units of this EPR type in the running. So some descriptions in the part should be updated as such: AP1000 (in China, the U.S.), EPR (in China, Finland, France and UK).	Accepted. The figures are updated. The most up to date source on the status of new constructions, grid connections, decommissioning is: https://pris.iaea.org/PRIS/home.aspx	Xiusheng Zhao	Tsinghua University	China
32275	39	47	40	1	I propose "...under construction or recently commited to the grid... EPR (China, Finland, France, UK)...." because it appears not a good idea to squeeze the first gen III reactors, which are currently in operation in China	Accepted. Text revised	Jean-Guy Devezeaux de Lavergne	Commissariat à l'Energie Atomique et aux Energies Alternatives	France
8883	40	1	40	1	EPR units also exists in China, where 2 units are also in operation at Taïshan.	Rejected. Text refers to the units under construction.	Michel SIMON	Vice Président SFENRAL	France
14497	40	2	40	4	Why is it that these reactors are better on these fronts, especially for the "enhanced safety systems"?	Noted. An example case is described: https://www.sciencedirect.com/science/article/pii/S2095809916301515	Jean-Sébastien Landry	Environment and Climate Change Canada	Canada
27929	40	5	40	22	The discussion of SMRs does not discuss any of the risks or potential problems: Greater weapons proliferation risk (due to spreading them worldwide), meltdown risk, radiation leak risk, waste risk, uranium mining lung cancer, uncertain costs, Given this tech is not commercialized, saying rosy things about it without acknowledging weaknesses misleads people into thinking this is a technology that may help when there is no evidence to date that it will.	Rejected. All these issues are important. Nuclear industry and the NPP market are highly regulated at both national and international levels. All countries wishing to use nuclear power should comply with all these non proliferation rules and safety standards.	Mark Jacobson	Stanford University	United States of America

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34115	40	5	40	22	Only three reactors are really being constructed (in Schneider et al.2019, World Nuclear Industry Status Report. Most projects are abandoned or stalled. Although market potentiel is more important that large scale reactors, cost issues are even more a problem, and siting (outside existing nuclear sites) is exactly the same as for the larger ones. Thus SMRs has no serious place in IPCC scenarios.	Rejected. Text provides references to latest status of SMRs	Antoine BONDUELLE	Climate Action Network France	France
35437	40	5	40	22	According to the reference synthesis World Nuclear Industry Status Report (Schneider, 2019), as of July 2019, only a very limited number of projects actually resulted in construction (one in Argentina, one in China and the floating Akademik Lomonosov in Russia). Other projects keep stagnating or are abandonned. According to the World Nuclear Report, SMR are not to play a role in the future, costs being too high. « Although policymakers in many countries continue to be interested in SMRs, it has become evident that they will be even less capable of competing economically than large nuclear plants, which have themselves been increasingly uncompetitive. Thus, even if a few SMR projects get built over the next decade or beyond, typically as a result of massive support from one or more governments, it is unlikely that SMRs could play any significant role in the future electricity sector. » (WNISR 2019, p. 209).	Noted	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France
8885	40	10	40	11	The most advanced SMR project has reached commercial operation, on board of LOMONOSOV ship in the northern sea of Siberia.	Noed	Michel SIMON	Vice Président SFENRAL	France
34117	40	16	40	19	This sentence is misleading. Accident risk are still there and SMRs would still produce nuclear waste. Guessing that public acceptance will be better than for existing models is wishfull thinking and has no place in this report.	Accepted. Text revised	Antoine BONDUELLE	Climate Action Network France	France
35439	40	16	40	19	Though smaller than units being currently built, SMR are no « pocket reactors ». Accident risk cannot be excluded and they will still produce nuclear waste. The effects on public acceptance may thus be very limited.	Accepted. Text revised	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France
14499	40	17	40	17	Explain or give an example to help readers understand these "advanced solutions related to safety".	Noted. Indeed, text provides some examples but there is no space to expand the discussion on them. Active safety systems would be eliminated by design. Using passive safety systems, minimal-to-no electrical power is required to actuate safety systems and provide long-term core cooling in the case of an accident.	Jean-Sébastien Landry	Environment and Climate Change Canada	Canada
14501	40	20	40	20	"[O]ffer increased load following capability" - by how much and why are they able to do so?	Noted. In generaly, they are designed to offer this option.	Jean-Sébastien Landry	Environment and Climate Change Canada	Canada
15079	40	21	40	21	first appearance of "VRE" - an abbreviation without the full expression	Accepted. Text revised.	Béla Munkácsy	ELTE University	Hungary
18697	40	21	40	22	Their market development will strongly depend on the successful deployment of prototypes and first-of-a-kind plants' - suggest also adding 'and their ability to compete with other low-carbon technologies on a number of metrics, including LCOE.'	Accepted. Text revised.	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
12635	40	24	40	27	Very large research budgets have been have been used to push nuclear forward, with little success in terms of cost reductions. What is the argument that this technology in particular should receive more support - at the expense of renewable technologies with great success in terms cost reductions? In general the chapter reads as if there is consensus that new nuclear is a necessity. Please provide references for that or rephrase.	Rejected. It does not suggest that nuclear is a necessity, but a potential part of solution, and it needs certain attention in order to be deployed in case countries choose this option.	Marie Münster	Technical University of Denmark	Denmark
10901	40	28	40	28	I am not sure that nuclear costs are as front-loaded as suggested and think the statement needs to be nuanced to take into account decommissioning costs and the ongoing costs of waste containment and management even if facilities for these are constructed in advance of commisisoning.	Rejected. These costs are internalised in the price of electricity during the operational life time of nuclear power.	Ian Bailey	University of Plymouth	United Kingdom (of Great Britain and Northern Ireland)
15075	40	28	40	28	"they are relatively expensive to build but relatively inexpensive to operate" - they are definitely expensive to build; relatively inexpensive to operate; but extremely expensive to cover all the costs of dismantling, disposing and managing the nuclear waste for 100s of thousands of years	Rejected. These costs are internalised in the price of electricity during the operational life time of nuclear power.	Béla Munkácsy	ELTE University	Hungary
12627	40	28	40	29	"Nuclear power plants have a front-loaded cost structure; they are relatively expensive to build but relatively inexpensive to operate." Please provide references and ensure that the costs of safe storage of nuclear waste and subsequent safe decommissioning of nuclear plants is taken into account. Currently it seems only to take investment and narrowly defined operation costs into account.	Rejected. These costs are internalised in the price of electricity during the operational life time of nuclear power.	Marie Münster	Technical University of Denmark	Denmark
35441	40	28	40	29	This does not take into account the fact that LCOE do increase with the necessity of refurbishment works in ageing plants.	Rejected. Refurbishment is applicable to all technologies.	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France
35443	40	28	40	29	Waste management and decommissioning cost also have to be taken into account	Rejected. These costs are internalised in the price of electricity during the operational life time of nuclear power.	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
27931	40	28	40	30	Nuclear power plants have high operational costs as well, especially as they age. Otherwise, why would so many nuclear plants today need subsidy to stay open? Please correct.	Rejected. Refurbishments are investments, not operational costs (like in hydro, change of turbines, construction work…)	Mark Jacobson	Stanford University	United States of America
34119	40	28	40	30	Do these figures account also for waste management and decommissioning costs?	Rejected. These costs are internalised in the price of electricity during the operational life time of nuclear power.	Antoine BONDUELLE	Climate Action Network France	France
6363	40	28	41	4	It is recommended that the economic aspects of Nuclear power plant are expanded and presented more in more details and with some quantifications. Currently the section does not clearly quantify i) the specific cost of nuclear energy, hence does not allow direct comparison with the other form of energy generation presented in section 6.4.2. and ii) does not comment on the issues of forecasted vs actual investments costs nuclear energy, where the actual costs of recent or undergoing projects have been systematically higher that the initial estimations. For example, IEA report 'Nuclear Power in a Clean Energy System' puts the cost of nuclear around 40-55$/MWh but actual costs, for example Hinkley C project in the UK, are expected to be 90-100£/MWh	Accepted. Text is revised to expand on economic assessment of nuclear power	Sciacovelli Adriano	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
15077	40	28	41	4	In the section "Economic" some of the important internal and external costs are neglected to mention (cost of waste management; Insurance coverage for nuclear accidents)	Rejected. These costs are internalised in the price of electricity during the operational life time of nuclear power. Concerning coverage for nuclear accidents, this is a complex topic and depends a lot on severity of the accident. Please see https://www.sciencedirect.com/science/article/pii/S0957582016303032 for a short but rather comprehensive discussion on the topic.	Béla Munkácsy	ELTE University	Hungary
20379	40	28	41	4	the disastrous economics of nuclear have to be better reflected; it is not really about market constraints, but due to extremely high electricity generation costs of nuclear, why nuclear is phased out without massive subsidies. Cost discussion of nuclear is provided by Ram et al. (https://www.sciencedirect.com/science/article/pii/S0959652618321486) and also provided by Lazard (https://www.lazard.com/media/451086/lazards-levelized-cost-of-energy-version-130-vf.pdf)	Accepted. Text is revised to expand on economic assessment of nuclear power	Christian Breyer	LUT University	Finland
37851	40	28	41	4	This section on the economics of nuclear should also discuss recent developments in the cost of new nuclear installations. Nuclear power projects in Europe have faced massive delays and drastic cost overruns. Grubler (2010) (doi 10.1016/j.enpol.2010.05.003) demonstrates negative learning in nuclear in France. In China, by contrast, installation costs seem to be substantially cheaper. These developments should be discussed carefully, since they are the determinant of the economic viability of nuclear.	Accepted. Text is revised to expand on economic assessment of nuclear power, including several recent examples	Gunnar Luderer	Potsdam Instittute for Climate Impact Research	Germany
8887	40	30	40	30	The figure : 90% of NPP are state owned is highly surprising: Most of the NPP in the USA, Germany, Belgium, Japan, .. are owned by private companies (even if the State owns a minority share). If the figure given (90%) was to be maintained, the reference of the study leading to that result should be given.	Rejected. The text refers to nuclear power projects under construction only	Michel SIMON	Vice Président SFENRAL	France
12637	40	31	40	32	"Sustained favorable political and financial framework conditions are crucial for new nuclear builds". This is again arguing as if new nuclear builds are necessary/ desirable. Please provide references for that or rephrase.	Accepted. Text revised to : are crucial if countries wish to deploy nuclear power.	Marie Münster	Technical University of Denmark	Denmark
12639	40	33	40	33	"In the absence of adequate political support, financing is often a major hurdle to project development" Sounds like the problem is the support and not the high costs. Please provide references for that or rephrase.	Rejected. It is clear from the paragraph that financing risk is related to high up-front capital costs. In addition, the very high initial costs are again mentioned on page 40, line 3.	Marie Münster	Technical University of Denmark	Denmark
14503	40	41	41	4	Much of this text is not specific to nuclear technology; does not seem to belong here, but rather to a more general section about ongoing and future transformation of electricity markets.	Accepted. Text is revised to emphasise more general market orriented changes that affect nuclear ecnomics	Jean-Sébastien Landry	Environment and Climate Change Canada	Canada
32277	40	43	40	43	I propose: "including nuclear energy. The main reason is that nuclear energy rarely benefits from the same advantages which have been designed for the other low carbon technologies such as solar or wind (Feed in Tariffs, Strike Prices etc…)"	Noted	Jean-Guy Devezeaux de Lavergne	Commissariat à l'Energie Atomique et aux Energies Alternatives	France
12631	40	43	40	47	Please rephrase. As nuclear is normally central and inflexible operated due to economic or technical reasons, it too provides high costs in terms of transmission capacity required and storage/ flexibility to match demand to production. Blaming the VRE for the costs associated with that with a blind eye to the costs associated with integrating nuclear seems biased. In general the claims should be substantiated with solid references.	Accepted. Text is revised to emphasise more general market orriented changes that affect nuclear ecnomics	Marie Münster	Technical University of Denmark	Denmark
18617	40	43	40	48	"costs associated with [VRE] (…) are not properly allocated in most markets", this claims needs to be substantiated. I suggest Hu et al. (2018) (doi.org/10.1016/j.rser.2017.06.028), who go through listing the main obstacles that need to be tackled so that the markets can accommodate the high-share penetration of VRE.	Accepted. Text is revised to emphasise more general market orriented changes that affect nuclear ecnomics	Thomas Gibon	Luxembourg Institute of Science and Technology (LIST)	France
6365	40	48	41	1	Please revise the sentence. Nuclear power plant is recognized as baseload generation; due to its technical nature it is quite inflexible and unable to provide flexibility services (like peaking plants).	Rejected. Nuclear power plants have the technical potential to provide these services	Sciacovelli Adriano	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
20751	40				Costs of nuclear power plant are not discribed in quantitative term as for solar and wind	Accepted. Text is revised to expand on economic assessment of nuclear power, including several recent examples	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	China
12633	41	2	41	4	Please rephrase. Remuneration of flexibility service should be determined by the value of the service to the market, not by a wish to keep specfic technologies in the market. If not, this is a market problem, not specific for nuclear (or renewable) technologies.	Rejected. The paragraph, although it is revised, empahsises the need for a level playing field in electricity markets.	Marie Münster	Technical University of Denmark	Denmark
32279	41	4	41	4	I propose to explain a little bit more what is said in the text with a good accuracy, when adding: "... of flexibility service. These defaults in the present economic design should be corrected, reflecting the value which nuclear power brings to the electric systems".	Accepted. Text is revised to expand on economic assessment of nuclear power, including several recent examples	Jean-Guy Devezeaux de Lavergne	Commissariat à l'Energie Atomique et aux Energies Alternatives	France
6367	41	5	41	5	It is recommended to state that nuclear is a baseload technology rather that dispatchable	Rejected. Nuclear power plants have the technical potential to provide flexibility	Sciacovelli Adriano	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
13853	41	5	41	6	Suggestion of clarification : "Over the past 50 years, the use of nuclear power has reduced CO2 emissions by over 60 gigatonnes", IEA 2019 : https://www.iea.org/reports/nuclear-power-in-a-clean-energy-system	Noted	Alexandre Bizeul	International Energy Agency	France
15081	41	5	41	6	"nuclear power can contribute to climate change mitigation as well as to system reliability, adequacy and energy security" - Nuclear capacity is relatively small, power plants take too long to build, therefore it is not possible to build enough nuclear plants in time to make a difference	Noted. Nuclear is part of generaltion portfolio and contributes to climate change mitigation. The same applies for the future for countries that wish to deploy nuclear power.	Béla Munkácsy	ELTE University	Hungary
27933	41	5	41	6	IPCC states, "As a dispatchable low carbon technology, nuclear power can contribute to climate change mitigation as well as to system reliability, adequacy and energy security." However, this statement is misleading and largely false. To the contrary, it is impossible for nuclear to play any role in obtaining the necessary 80% reduction in global energy emissions needed by 2030 to avoid 1.5 C warming. The simple reason is that all nuclear plants worldwide require 10 to 19 years or more between planning and operation (see Section 3.3.1.1 of https://web.stanford.edu/group/efmh/jacobson/Articles/I/NuclearVsWWS.pdf for data as well as Jacobson, M.Z., Review of solutions to global warming, air pollution, and energy security, Energy & Environmental Science, 2, 148-173, doi:10.1039/b809990c, 2009), so a single nuclear plant planned today will not be online until around 2035 on average, preventing any nuclear plant planned today from playing any role in CO2 mitigation between 2020 and 2030, when it is most needed. On top of that, nuclear costs 4-5 times that of onshore wind or utility PV per unit energy, so spending a dollar on it increases CO2 relative to spending the same on wind/solar. Please clarify the text to state this. Otherwise, the text will mislead readers into thinking nuclear will help the climate situation.	Rejected. Nuclear is part of generaltion portfolio and as such contributes to climate change mitigation. The same applies for the future for countries that have NPPs under construction or planning to deploy nuclear power. Over the past 50 years, the use of nuclear power has reduced CO2 emissions by over 60 gigatonnes", IEA 2019 : https://www.iea.org/reports/nuclear-power-in-a-clean-energy-system	Mark Jacobson	Stanford University	United States of America
43569	41	5	41	6	" nuclear power can contribute to climate change mitigation as well as to system reliability, adequacy, energy security" Add: "and biodiversity (Brook 2015) ". There is an important publication that can be refferenced here: "Key role for nuclear energy in global biodiversity conservation" Brook at all 2015 in Conservation Biology https://conbio.onlinelibrary.wiley.com/doi/pdf/10.1111/cobi.12433	Noted	Adam Blazowski	FOTA4Climate.org	Poland
34121	41	5	41	9	Pollution and accidents are also a large impact and risk. This paragraph is not balanced.	Accepted. Text revised	Antoine BONDUELLE	Climate Action Network France	France
35445	41	5	41	9	This paragraph over-emphasizes some aspects while forgetting important environmental issues such as the pollution generated by uranium mining and milling, impact on water biodiversity through heating of river waters, radioactive and chemical releases generated by reprocessing facilities, the production of nuclear waste that will remain dangerous for millions of years and, of course, accident risk.	Rejected. Most common LCA impact categories relevant for nuclear energy are mentioned in the text. In addition, text is revised and complemented with literature sources.	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France
12005	41	5	41	14	To me this text seems unbalanced. Please consider issues related to waste, safety and weapon profiliation. For existing power plants it has also been identified that many of them (at least in Europe) are situated close to the sea (due to the need for cooling water) and may be vulnerable to sea level rise. Other are situated along rivers and may be sensitive to changes in the hydrology due to climate change.	Rejected. The text discusses these issues to the extent of allowed space. All these issues are relevant and they are taken into account when assessing future enery supply options by countries.	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
6369	41	5	41	15	Among the environmental aspects there is no mention at all of management and disposal of nuclear waste. this should be included to present a comprehensive view of environmental aspects of nuclear energy.	Accepted. Text revised.	Sciacovelli Adriano	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
14505	41	5	41	20	This section on the "environmental/ecological" considerations of nuclear energy must address the issue of nuclear waste.	Accepted. Text revised.	Jean-Sébastien Landry	Environment and Climate Change Canada	Canada
14507	41	5	41	20	This section currently comes across as presenting pro-nuclear advocacy instead of a balanced assessment.	Rejected. The claim for an unbalanced and overly optimistic treatment would need to be better substantiated.	Jean-Sébastien Landry	Environment and Climate Change Canada	Canada

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15087	41	5	41	20	The most crutial problem, the nuclear waste is completely missing from the section "Environment"!! The huge negative environmental impacts of the nuclear disasters (INES 4-7) are also completely missing!!	Accepted. Text revised.	Béla Munkácsy	ELTE University	Hungary
34689	41	5	41	20	If we consider all thelife cycle of the nuclear power plants they are not carbon zero emitors (Manfred Lenzen,Life cycle energy and greenhouse gas emissions of nuclear energy: A review,Energy Conversion and Management,Volume 49, Issue 8,2008,Pages 2178-2199,ISSN 0196-8904,https://doi.org/10.1016/j.enconman.2008.01.033.)	Rejected. It says low carbon not zero.	Jordi Solé-Ollé	Spanish National Research Council (CSIC)	Spain
15083	41	7	41	9	"having a very small impact on ecosystems compared to alternatives" - according to the Swiss Federal Statistical Office, the impact of nuclear energy in significant: 17% of the whole ecological footprint of the country: https://www.bfs.admin.ch/bfs/en/home/statistics/sustainable-development.assetdetail.343230.html	Rejected. The methodology of "ecological footprint" is based on unbalanced treatment of various energy options. In addition, "ecological footprinty" is absent from common LCA impact categories.	Béla Munkácsy	ELTE University	Hungary
12629	41	8	41	9	"On a life cycle basis, nuclear power is among technologies with the lowest acidification and eutrophication potentials, thus having a very small impact on ecosystems compared to alternatives." This comments ignores the risks and impacts on the environment in terms of nuclear accidents such as Fukushima. Instead it focuses only on eutrofication and acidification, which is not a sufficiently wide scope in terms of comparing nuclear power with other technologies. Further impact categories should be considered such as abiotic depletion, Human Toxicity, Freshwater Aquatic Ecotoxicity, Marine Aquatic Ecotoxicology, and Terrestrial Ecotoxicity. See e.g. https://doi.org/10.3390/su8111097	Accepted. Text is revised with regards to nuclear accidents. Not all LCA impact categories can be considered because of space restrictions, and only the most relevant indicators to particular technologies were suggested to be included.	Marie Münster	Technical University of Denmark	Denmark
34123	41	9	41	11	If one includes the exclusion zone in Chernobyl and Fukushima this part should come with a grain of salt. Add to this abandoned uranium mines and waste deposit, and the whole paragraph is misleading	Rejected. The environmental indicators refer to normal operation only. The text is revised regarding nuclear accidents.	Antoine BONDUELLE	Climate Action Network France	France
35447	41	9	41	11	The assertion on limited land use requires balancing. The land footprint of a plant may be small, but the footprint of current and abandoned uranium mines should also be taken into account. Moreover, as explained in Chapter 12 (p.40, l.32-43), areas contaminated by nuclear accidents (Chernobyl, Fukushima, Kyshtym) should be taken into account.	Rejected. Not supported by the peer-reviewed published literature	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France
18615	41	12	41	14	For the claim of nuclear having low human health impact, you may consider the following (slightly more recent) sources in addition: Gibon et al. (2017) (doi.org/10.1088/1748-9326/aa6047) or Luderer et al. (2019) (https://doi.org/10.1038/s41467-019-13067-8, especially the Supplementary Information, which provides updated per-kWh environmental impact values). This comment is valid for all mentions of other environmental impact indicators. In addition, the IAEA (2016) report (cited) originally uses third-party sources, such as Treyer et al. (2014) (https://doi.org/10.1016/j.enpol.2014.03.034), which you may consider as a primary source too.	Accepted. Text and reference revised accordingly	Thomas Gibon	Luxembourg Institute of Science and Technology (LIST)	France
35449	41	12	41	14	The low health impact of nuclear power is an highly controversial argument. An international study stated a higher incidence of lung cancer among nuclear industry workers (Cardis et al., 2007 https://www.ncbi.nlm.nih.gov/pubmed/17388693). This study does not even take into account miners nor subcontracting workers, whose exposure to radiation is higher. Health impacts of nuclear accidents are difficult to assess precisely due to the lack of large-scale surveys but some independent studies point an excess of thyroid cancer related to the Chernobyl accident (TORCH, 2016 https://www.global2000.at/sites/global/files/GLOBAL_TORCH%202016_rz_WEB_KORR.pdf) as well as a higher rate of cardiovascular pathologies among children of the areas concerned by Chernobyl fallout (Bandazehvsky et al, 2015 : https://chernobyl-today.org/images/stories/CARDIOVASCULAR_SYSTEM_eng.pdf). An increase of cancer among Chernobyl clean-up workers was also documented (Fernex, M., Knüsli, C., Nidecker, A., & Walter, M. (2006) : Health of Liquidators (Clean-up Workers),20 Years after the Chernobyl Explosion. PSR/IPPNW Switzerland)/ As for Fukushima, 186 thyroid cancer cases have already been assessed among children, 15-fold more than what could be expected (http://fukushimavoice-eng2.blogspot.com/)	Rejected. The text under Environmenttal/Ecological refers to normal operation only. The text is revised regarding nuclear accidents.	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France
34125	41	15	41	16	Nuclear power and well-being of citizen is just ideology not peer reviewed argument	Rejected. Lines 15 and 16 apply to all energy supply technologies	Antoine BONDUELLE	Climate Action Network France	France
35451	41	15	41	16	The association between nuclear power and well-being of citizen does not rely on any scientific study.	Rejected. Lines 15 and 16 apply to all energy supply technologies	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France
6167	41	15	41	20	The section on jobs related to nuclear is contradictory with others. The job intensity of nuclear is much lower than for other technologies, so mentioning this as an advantage of this technology is not consistent with the evidence and with previous statements about other technologies	Rejected. The text does not compare technologies based on Job Intensity. It says that nuclear requires highly skilled labour force.	Linares Pedro	Universidad Pontificia Comillas	Spain
15085	41	16	41	17	"creates many long-term jobs in operations, contracting and in the supply chain" - only in some cities, but it does not have any impact on the increasing job problems in rural areas	Rejected - outside the scope of analysis and space. If plant does not create jobs in rural areas then it is not a good choice?..	Béla Munkácsy	ELTE University	Hungary

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34127	41	16	41	17	Nuclear power is much less job-intensive than renewable energies and energy conservation technologies.	Rejected. The text does not compare technologies based on Job Intensity. It says that nuclear requires highly skilled labour force, it is about skills, education.	Antoine BONDUELLE	Climate Action Network France	France
35453	41	16	41	17	Nuclear power is much less job-intensive than renewable energies and energy conservation technologies. For example, a French study shows that the transition towards 100% renewable in France (and thus phasing out of nuclear energy) would result in 600 000 net job creations. Quirion, Ph, L'effet net sur l'emploi de la transition énergétique en France : une analyse input-output du scénario négaWatt, CIRED Working Papers, 2013	Rejected. The text does not compare technologies based on Job Intensity. It says that nuclear requires highly skilled labour force.	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France
14509	41	21	41	30	This section on the "sociocultural" considerations of nuclear energy comes across as arguing that people are wrong to fear nuclear energy. Suggest rewriting to address this and introducing studies showing that people tend to fear more the 'catastrophic' but unfrequent events (nuclear accident, plane crash, etc.) than chronic issues with similar or worst outcomes (smoking, coal-fired electricity, etc.).	Rejected. The text does not compare technologies based on Job Intensity. It says that nuclear requires highly skilled labour force.	Jean-Sébastien Landry	Environment and Climate Change Canada	Canada
35455	41	21	41	30	This paragraph is policy-prescriptive. It works on the assumption that the people opposing nuclear power are systematically wrong, which is equivalent to judging a social preference.	Rejected. The text says that nuclear technologies are complex and that understanding of the risks and benefits behind requires additional reliable and scientifically supported discussion.	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France
31819	41	22	41	22	Not only political and public support but also economics, which don't seem to favour it.	Noted	Ashok Sreenivas	Prayas (Energy Group)	India
15089	41	25	41	25	"risks can be exaggerated" - the lesson of the ten big nuclear disasters (INES 4-7) is that the risk can not be exaggerated.	Rejected. A study on severe accidents in alternative energy chains makes use of extensive historical experience (1970-2008). Please check the Reference: BURGHERR, P., HIRSCHBERG, S., Comparative risk assessment of severe accidents in the energy sector, Energy Policy 74 Suppl. 1 (2014) S45–S56.	Béla Munkácsy	ELTE University	Hungary
15091	41	26	41	26	"To maintain and increase public support" - it can be reached by significant PR campaigns, financed by the money of tax payers (360 million HUF/year in Hungary). This money should be cover energy efficiency programs.	Noted	Béla Munkácsy	ELTE University	Hungary
43571	41	26	41	26	"There is also some evidence of popular media bias against nuclear power in some countries, as antinuclear activists/contrarians are often quoted as nuclear experts." Research done by Merkley 2020. https://www.researchgate.net/publication/339324276_Are_Experts_NewsWorthy_Balance_Conflict_and_Mass_Media_Coverage_of_Expert_Consensus Fig3	Noted	Adam Blazowski	FOTA4Climate.org	Poland
35457	41	26	41	28	This sentence is contradictory. A fair decision-making process should include and accept the possibility that citizen could refuse nuclear projects.	Noted. This is how it is done.	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France
35459	41	28	41	30	This example is controversial. A communication campaign to improve social acceptability is not similar to a fair decision-making process.	Rejected. Communication to increase the knowledge and provide full information on complex technologies such as nuclear.	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France
27935	41	31	41	32	IPCC states, "Public concerns about nuclear power are in many cases related to issues of safety, security, waste management, and proliferation." An additional issue is underground uranium mining lung cancer risk as, for example, over 10% of all underground uranium miners die of lung cancer, according to NIOSH https://www.cdc.gov/niosh/pgms/worknotify/uranium.html. In addition, weapons proliferation is a major concern, but it is not discussed at all, Further, 1.5% of all nuclear reactors ever built have melted down, and Fukushima itself cost over $500 billion, but the document downplays that risk, claiming that the risk can be reduced by informing the public it is not real. Here is a summary of risks, with details, https://web.stanford.edu/group/efmh/jacobson/Articles/I/NuclearVsWWS.pdf, which is from Jacobson, M.Z., 100% Clean, Renewable Energy and Storage for Everything, Cambridge University Press, New York, 2020.	Rejected. The text refers to normal operation of NPPs. The text is revised regarding nuclear accidents. Also,a study on severe accidents in alternative energy chains makes use of extensive historical experience (1970-2008). Please check the Reference: BURGHERR, P., HIRSCHBERG, S., Comparative risk assessment of severe accidents in the energy sector, Energy Policy 74 Suppl. 1 (2014) S45–S56.	Mark Jacobson	Stanford University	United States of America
34129	41	32	41	33	This part of reasoning is sophist, because the argument of safety standards motivated by an accident does not make the consequences of the accident disappear.	Accepted. The text on nuclear accident is revised.	Antoine BONDUELLE	Climate Action Network France	France
35461	41	32	41	33	This wording is paradoxical. Mentionning an increase of safety standards should not conceal the fact that a major nuclear accident has actually happened, with long-term consequences.	Noted	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France

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32281	41	35	41	37	I propose: " Nuclear power can be devellopped only if it appears safe and used solely for peaceful purposes. Safety has been reinforced (post-Fukushima requirements) and is mainly regulated at the level of the states. Risks of proliferations are mastered through safeguards measures (including activities of the IAEA and others) for all the countries which have signed the non-proliferation treaty. This is needed to build confidence and foster and secure technical co-operation."	Accepted. Text revised	Jean-Guy Devezeaux de Lavergne	Commissariat à l'Energie Atomique et aux Energies Alternatives	France
34131	41	35	41	37	This sentence contains no factual information but wishful thinking	Noted	Antoine BONDUELLE	Climate Action Network France	France
35463	41	35	41	37	This sentence contains no factual information but wishful thinking	Noted	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France
4455	41	38	41	39	How do you substantiate the claim that "In particular public confidence could be improved with the opening of the first disposal facility for high level 39 waste (HLW)." Are there any studies behind?	Noted. Could or might be improved. No studies behind. Generally when something is realised makes people more confident.	Leonardo Barreto	Austrian Energy Agency	Austria
34133	41	38	41	43	Public confidence in nuclear power is not only related to the waste issue but also to risks to public companies, risk of accident for example.	Rejected. Overall text covers all these aspects/concerns	Antoine BONDUELLE	Climate Action Network France	France
35465	41	38	41	43	Public confidence in nuclear power is not only related to the waste issue. The opening of a high-level waste repository will not solve the problem of accident risk and uranium mining pollution.	Rejected. Overall text covers all these aspects/concerns	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France
35467	41	38	41	43	Most high-level waste repository projects are highly contested with consideration to safety, technical feasability and costs. The French Court of Auditors (Cour des Comptes) itself expressed important concerns about the incertitudes and unrealistic cost-estimation of Cigéo, the French deep geological disposal projects (https://www.ccomptes.fr/fr/publications/laval-du-cycle-du-combustible-nucleaire)	Noted	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France
6371	41	38	41	48	Please report some example of half-life time for HLW and for low/intermediate level waste	Rejected. Too technical and space restricted.The nuclear waste management is highly regulated.	Sciacovelli Adriano	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
16271	41	38	41	48	The text related to longterm geological storage of nuclear materials could be improved by emphasizing that current designs for dry casks use copper or other metals which are subject to corrosion, and are thus not up to the task. Geologic storage is elusive when one considers the dynamic nature of the Earth system and the long times involved. Likewise, costs of long term storage are borne by future generations, and this is not adequately addressed in the text currently.	Rejected. Too technical and space restrcited.	Daniel Helman	College of Micronesia-FSM	Micronesia, Federated States of
16671	41	38			About HLW, public confidence will not be easily improved: as a rule, people felll uncomfortable with undergroud repositories of potentially harmful waste under their feet. This statrement also holds for underground CO2 sequesration. Radiactivity and CO2 molecules appear to many as invisible malicious dangers.	Noted. Could or might be improved. Generally when something is realised makes people more confident.	Jean Louis Bobin	Sorbonne universités Paris	France
34161	41	40	41	41	Maybe mention the part reuse of some of the fuels as MOx in IV generation reactors: https//www.sciencedirect.com/science/article/pii/S0360544214002035 [suggestion ENSEEIHT INP]	Noted	Antoine BONDUELLE	Climate Action Network France	France
12641	41	41	41	43	Please add references: "Regarding the HLW, scientific consensus is that the safety and isolation of the disposed HLW from the environment can be assured in stable geological formations combined with multiple engineered barriers."	Accepted. Reference added.	Marie Münster	Technical University of Denmark	Denmark
12897	41	41	41	43	To include - India's pioneering work in actinide partioning of high level liquid waste is a first technological milestone. Further in the Indian context, partitioned minor actinides could be routed into the fast breeder reactor systems scheduled for commissioning in the near time frame. In addition, further work on burning of long lived minor actinides in Accelerator Driven Systems would substantially reduce the waste volume and radiotoxicity, which would prolong the requirement for setting up of HLW disposal facilities.	Noted	ASHOK NEMA	Nuclear Power Corporation of India Limited	India
8889	41	46	41	46	The finnish final HLW depository is located in Onkalo. Olkiluoto is close from Onkalo and hosts the finnish EPR.	Accepted. Text revised.	Michel SIMON	Vice Président SFENRAL	France
15093	41	47	41	48	"the Swedish Nuclear Fuel and Waste Management Company applied for a construction license for Sweden's disposal facility at Forsmark" - according to the Swedish Land and Environmental Court it was not certain of the proposed repository's safety.	Noted	Béla Munkácsy	ELTE University	Hungary
34135	42	1	42	2	"Inadequate political support" is not in the IPCC mission, especially here because cheaper options do exist and are described in the rest of the report	Rejected. The text refers to level playing field among technologies, the choice will be done by countries.	Antoine BONDUELLE	Climate Action Network France	France
35469	42	1	42	2	Mentioning "inadequate political support" is policy-prescriptive.	Rejected. The text refers to level playing field among technologies, the choice will be done by countries.	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
8891	42	1	42	6	I suggest you mention that public acceptance is difficult as long as anti nuclear organisation are very active, exagerating the risks or confusing danger and actual risk, propagating sometimes fake news, reported in the media with some complacency	Noted	Michel SIMON	Vice Président SFENRAL	France
12007	42	1	42	6	I believe that one reason for the slow rates of deployment also is that the risk (even if the probability is very low) makes it impossible for a private company to insure such a plant and that development then have to rely of financing or guarantees from the state. Hence this might be more than normal financial issues. Market liberalization is the same for all technologies (but it can still be negotiated long term sales agreements) and also other technologies have large investment costs. It can also be seen in another way: Large investment cost combined with less short time flexibility may impact the price that can be achieved on the produced electricity and the market opportunities. Eg. long-term stable contracts may be obtained with industrial companies which have a more stable demand but pay less for the electricity.	Noted	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
14511	42	1	42	6	This section on the "institutional" considerations of nuclear energy comes across as pro-nuclear advocacy. Two examples. First, the "political support" for nuclear is considered "inadequate". Second, why is it that "structural market deficiencies" would unduly impact a source of energy which, like nuclear, has been around for decades (markets are typically more biased against emerging rather than dominant technologies)?	Rejected. The claim for pro-nuclear advocacy would need to be better substantiated. (1) For inadequete political support, some benefits of nuclear power, e.g. low carbon, stable, reliable electricity, are simply not properly reflected in policies. (2) Market changes are too slow compared to technological changes. For example, out of market payments (feed-in tariffs, premium tariffs) to variable renewable energy sources, do not create a level playing field for all low carbon technologies.	Jean-Sébastien Landry	Environment and Climate Change Canada	Canada
16273	42	1	42	6	In the [Institutional] section on nuclear power adoption, consider adding a fifth category responsible for slow deployment: risk of nuclear arms proliferation and other security issues. Including this will give a clearer picture of the institutional challenges to increased adoption.	Rejected. These are inherent to (1) category	Daniel Helman	College of Micronesia-FSM	Micronesia, Federated States of
20381	42	1	42	6	better mention also the massive cost and budget overruns, which is an inherently issue for nuclear projects all around the world, as documented by Sovacool: https://www.sciencedirect.com/science/article/pii/S0360544214008925 (Fig. 5)	Accepted. Text revised	Christian Breyer	LUT University	Finland
16673	42	1			Nuclear power plants face vigourous opposiitons from environmentalists among which NGO and "green" politicians are very active. About the elecricity markets in Europe, they are definitely distorted. In France EDF is ciommited by law to sell power from nuclear plants to competitors at rates well below the average market price. However, the competition remains somewhat fictitious. In order to maintain active profitable competitors, prices payed by individual customers are raising.	Rejected. The discussion on nuclear power plants and electricity markets is not a part of this section and discussed elsewhere.	Jean Louis Bobin	Sorbonne universités Paris	France
15095	42	2	42	3	"e.g. Chernobyl and Fukushima" - there were at least 10 significant (INES 4-7) events, that would be important to clarify	Rejected. There were three big scale accidents: Chernobyl, Fukushima and Three Miles. The two biggest are given as examples.	Béla Munkácsy	ELTE University	Hungary
34137	42	2	42	3	Accidents did happen in the past with grave consequences. This sentence suggest that this could not happen any more and is misleading.	Rejected. Sentence does not in any way suggest this.	Antoine BONDUELLE	Climate Action Network France	France
35471	42	2	42	3	The formulation «mainly driven by various facility accidents in the past » implies that such accidents belong to the past and are unlikely to take place again in the future. The French Nuclear Safety Authority keeps saying that "a major accident is possible in France" and recently opened a website on post-accidental issues (https://post-accident-nucleaire.fr/)	Rejected. Sentence speaks about the past only.	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France
32283	42	3	42	3	I propose: " (2) too high initial costs and complex financing arrangements". In fact, costs are important mainly in Europe and in the US. In Europe at least, there is a strong work, leaded by EDF in France, which aims to decrease the clearly too high values obtained in Olkiluoto and Flamanville plants. The willingness of this plan is to decrease the cost by a factor of roughly 2, and reach a LCOE of 65-80 $/MWh. See: https://www.connaissancedesenergies.org/sites/default/files/pdf-pt-vue/les_couts_de_production_du_nouveau_nucleaire_francais.pdf	Noted. "Too" high would need some reference number and more explanation.	Jean-Guy Devezeaux de Lavergne	Commissariat à l'Energie Atomique et aux Energies Alternatives	France
32285	42	6	42	6	I propose: "….renewable energy sources (VRE)). There is an important evolution underway in deifferent countries to overcome these difficulties. Part of the actions are in the industrial domain. The main goal is to decrease the cost and the construction duration of the new NPPs (particularly in the US and in Europe).	Noted.	Jean-Guy Devezeaux de Lavergne	Commissariat à l'Energie Atomique et aux Energies Alternatives	France

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
34385	42	10	42	10	GENERAL COMMENT ABOUT CCUS (1): CCUS should be splitted into CCU and CCS: In the report, the term CCUS (Carbon Capture Utilisation and Storage) is broadly used but not clearly defined and in most cases, 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, 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 (REFERENCES:1) Cuéllar-Franca and Azapagic, 2015 (https://doi.org/10.1016/j.jcou.2014.12.001), 2) Bruhn et al.,Environmental Science & Policy 60 (2016) 38–43, 3) Arning et al., Energy Policy 125 (2019) 235–249).	Accepted. The differences between CCS and CCU have been clearly outlined with a much greater description of CCU than FOD.	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
34387	42	10	42	10	CCUS, What's new since AR5? Here again CCUS should be splitted into CCU and CCS.	Accepted. We have split the discussion here as well.	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
4453	42	10	42	44	The text under 6.4.2.5. does not make any mention to the energy efficiency of CCS technologies. Energy efficiency must be considered when choosing CCS technologies.	Taken into account. We have provided a table which discussed the energy efficiency of different technologies with and without CCS.	Leonardo Barreto	Austrian Energy Agency	Austria
6169	42	10	42	45	Along this section and others, and correspondingly with its title, CCS should be changed to CCUS, given that utilization will probably become an essential route to capture carbon. Accordingly, a discussion of the utilization of carbon should be included, instead of describing only storage options.	Accepted. The differences between CCS and CCU have been clearly outlined with a much greater description of CCU than FOD.	Linares Pedro	Universidad Pontificia Comillas	Spain
4881	42	10	44	32	This chapter should make use of recent literature that summarizes the current SOT in CCS including https://doi.org/10.1039/C7EE02342A (Bui et al. 2018)	Accepted. This has been added	Patrick Lamers	National Renewable Energy Laboratory	United States of America
16983	42	10	44	32	"6.4.2.5 Carbon Dioxide Capture, Utilization, and Storage" but this part only talks about the carbon dioxide capture (CCS). The sub-title should be changed. In addition, this part follows the energy sources discussions, they are not in the same aspect. Thus it is better to pick this part and descript it alone.	Accepted. The differences between CCS and CCU have been clearly outlined with a much greater description of CCU than FOD.	Qing YANG	Harvard University	China
20383	42	10	44	32	I am fully shocked!!! The section is CCU and CCS, but NOTHING, ABSOLUTELY NOTHING on CCU - what is going on here? First of all one has to structure CCU and differentiate from CCS, this can be done according to 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). Here is an example for linking CCU of a point source (cement mill) with a modern understanding of Power-to-X: https://www.sciencedirect.com/science/article/pii/S0959652619302185. SAPEA has published a very good report on CCU: https://www.sapea.info/wp-content/uploads/CCU-report-web-version.pdf . here an excellent article in PNAS on CCU for the chemical industry: https://www.pnas.org/content/116/23/11187 . Here an excellent report for chemical industry and fuels in the Power-to-X/CCU context: https://dechema.de/dechema_media/Downloads/Positionspapiere/Technology_study_Low_carbon_energy_and_feedstock_for_the_European_chemical_industry-p-20002750.pdf. Here a DACCU/PtX approach for fuels: https://www.sciencedirect.com/science/article/pii/S1876610216310761 ; https://www.mdpi.com/2071-1050/9/2/306 . The HUGE gap on CCU has to be fixed in this section with a MAJOR revision.	Accepted. The differences between CCS and CCU have been clearly outlined with a much greater description of CCU than FOD.	Christian Breyer	LUT University	Finland
27937	42	10	44	32	Please update this section with results from 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; which examined data from the Petra Nova coal-CCS/U plant in Texas, and found a net, over 20-100 years, of a CO2e savings (before even considering what happens to the captured CO2) of only 11-20% rather than the 88-97% claimed in Table 6.8. This section needs a thorough discussion of the opportunity cost that CCS/U represents and how it increases air pollution and mining while hardly reducing CO2e, and all at high cost. It also needs to discuss how much CO2goes back to the air from enhanced oil recovery. It also needs to discuss the CO2e from the upstream mining of fossils and from the fossil energy needed to power the equipment, as discussed in this paper.	Taken into account. We have tried to do an assessment across the breadth of literature.	Mark Jacobson	Stanford University	United States of America
39135	42	10	44	32	CCS is not belonging to energy source and energy conversion. So,, CCS is rather moved to 6.4.6 systems and system integration	Rejected. The section broadly described different elements of energy systems where CCS is pertinent in our view.	Dong-Woon NOH	Korea Energy Economics Institute	Republic of Korea
5721	42	10	44	36	The section as a whole doesn't mention the importance of capex reduction in CCS in reducing the overall LCOE. Efficiency penalty is great, but it really isn't most of the story. This is discussed in M Bui and co-authors Energy & Environmental Science 11 (5), 1062-1176. The value of CCS to the system as a whole is discussed in this paper as well, which is really what it is for.	Taken into account. We have not discussed this due to the page constraints but agree with the comment.	paul fennell	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
44603	42	10	44	36	There's not much on utilization in this section, which might not be a problem if you get rid of the term in the section title	Accepted. The differences between CCS and CCU have been clearly outlined with a much greater description of CCU than FOD.	Oliver Geden	German Institute for International and Security Affairs	Germany
46087	42	10	44	36	While CCUS is not energy source, it is listed here. If CCUS is listed here, other power-to-X technologies should be, like power-to-heat, power-to-mobility, etc.	Rejected. The section broadly described different elements of energy systems where CCS is pertinent in our view.	Neven Duic	University of Zagreb	Croatia
46089	42	10	44	36	should be about CCUS, but it is only about CCS. Where are e-fuels?	Taken into account. That discussion is elsewhere.	Neven Duic	University of Zagreb	Croatia
2151	42	11	42	12	This is only true if international agreements to limit greenhouse gas emissions are kept. If not, we don't need CCS, we can just keep using fossil fuels (and it's cheaper and easier to not use CCS)!	Accepted. The statement has been made conditional. More discussion can also be found in section 6.7.4 (Fossil fuels in transition).	Amy Townsend-Small	University of Cincinnati	United States of America
43851	42	12	42	12	SRCCL not SRCCS	Rejected. The reference here is made to the Special Report on CCS i.e. SRCCS.	Hans Poertner and Elvira Poloczanska	Alfred-Wegener-Institut	Germany
26209	42	14			What about CCS for industrial applications? Relevant for both combustion emissions and process emissions e.g. from cement, steel and chemcials production	Taken into account. This chapter is devoted to energy systems but some discussion of industrial CCS is provided.	Sara Budinis	International Energy Agency	France
30945	42	15	42	15	it is hinted at a separate ection on BECCS which is not provided	Taken into account. We have provided a discussion in this section of CCS with different fuels (including bioenergy). A separate section i.e. 6.4.2.6 has also been devoted to bioenergy.	Pietro Bartocci	University of Perugia	Italy
39283	42	16	42	16	Is geophysical really the good term ? The paragraph talks more about georessources than geophysics.	Rejected. The term geophysical here describes resources in the geosphere and is widely accepted.	Bruno Gavazzi	UMR7516 Institut de Physique du Globe de Strasbourg (CNRS/Université de Strasbourg	France
12371	42	23	42	23	IAM abbreviation should be explained first time it is used	Taken into account. While IAM abbreviation has been used for the first time in the section, it has been used multiple times in this chapter previously.	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
16985	42	27	42	28	There have been lots of researches studying country-level potential of CCS, not just China and India. It is suggested to make a better summary for the research status in country aspect.	Accepted. We have included text and a table on the regional potential of CCS in India. We are constrained by text and thus can provide only limited examples.	Qing YANG	Harvard University	China
29447	42	27	42	28	Please add the estimated global storage potential from IPCC 2005 SRCCS - the global storage resource potential is 2000Gt CO2e. Also state that the U.S. Department of Energy's (DOE) National Energy Technology Laboratory (NETL) reviewed the entire continent in the Storage Atlas V (5) between 2,618 and 21,633 billion metric tons alone. There is high confidence in these values as the US has been reviewing its storage resources continuously for over two decades. References: Benson et al., 2005. Underground geological storage. IPCC Special Report: Carbon Capture and Storage; US Depament of Energy and NETL. 2015. Carbon Storage Atlas (V), 114.	Accepted. The SRCCS values have been added and the US DOE Carbon Storage Atlas values have also been referred to, as an example of spatially-resolved exploration.	Eve Tamme	Global Carbon Capture and Storage Institute	Belgium
29449	42	27	42	28	there is low confidence in the storage resource estimates provided by Viebahn et al (2014; 2015).	Taken into account. There is low confidence in the storage resource estimates due to limited exploration of several storage sites but that discussion is beyond the scope of this report.	Eve Tamme	Global Carbon Capture and Storage Institute	Belgium
29457	42	27	42	28	Important to emphasise the global storage resource potential available for CCS. Suggest you add: Figure 10 Global Storage Resources from Global CCS Institute, 2019: Global Status Report 2019. https://www.globalccsinstitute.com/.	Taken into account. We have provided an alternative table for the regionally divided storage potential.	Eve Tamme	Global Carbon Capture and Storage Institute	Belgium
17527	42	29	42	40	EOR is a currently a major use of captured CO2, with about 1/3 of the CO2 used for oil recovery captured from natural gas plants, and has potential to grow in the future. However, there seems to be confusion about the intersection of this oil recovery operation with storage benefits. Some policy oriented papers downgrade the value of CO2- EOR as a storage mechanism because of oil production and others eliminated value completely, believing (erroneously) that the CO2 was released after production. A coherent and straightforward framework clarifies all the disparate terminologies and boundary conditions that created confusion. We now see that the "rule-of-thumb" input assumptions for the utilization ratio of CO2 used/oil produced are based on past conditions that are not relevant to future projects. Specifically, if capture is incentivized (as it is by the new 45Q tax credit), the optimum utilization ratio will likely change. To create "future-looking" scenarios, two models of CO2-EOR operations that are well constrained geologically and by production history were developed and calibrated and consider the life cycle implications of various operational decisions.	Accepted. We have provided an update on this with an assessment of the recent literature and the amount of net sequestered CO2 using EOR.	Katherine Romanak	The University 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
17529	42	29	42	40	A novel dynamic carbon lifecycle analysis (d-LCA) has been done with the never-before-used dynamic component as the key for understanding the evolution of the environmental impact (CO2 emissions) and mitigation (geologic CO2 storage) associated with carbon capture, utilization and storage (CCUS) systems, from start to closure of operations. Results showed that all CO2-EOR evaluated scenarios start operating with a negative carbon footprint and, years into the project, transitioned into operating with a positive carbon footprint. An important concluding remark is that the negative carbon footprint period could be engineered to last longer through operational changes and, more significantly, with stacked saline carbon storage	Accepted. We have provided an update on this with an assessment of the recent literature and the amount of net sequestered CO2 using EOR.	Katherine Romanak	The University of Texas at Austin	United States of America
17531	42	29	42	40	Nuñez-López, V., Gil-Egui, R., and Hosseini, S. A., 2019, Environmental and operational performance of CO2-EOR as a CCUS technology: a Cranfield example with dynamic LCA considerations: Energies, v. 12, no. 3, 15 p., http://doi.org/10.3390/en12030448.	Accepted. We have provided an update on this with an assessment of the recent literature and the amount of net sequestered CO2 using EOR.	Katherine Romanak	The University of Texas at Austin	United States of America
17533	42	29	42	40	This paper analyzes the results of the previously cited paper in the context of the urgency of climate change mitigation. “Acknowledging that fossil fuels currently provide the energy foundation upon which global societies function, and that a sudden shift in its composition can potentially destabilize the global economy and key elements of modern society, we bring CO2-EOR to the fore as it can supply reduced carbon oil to support the current energy foundation as it steadily transitions toward decarbonization.” The paper emphasizes (based on the d-LCA results) the timing of EOR net emission reductions (the first years, not the last) as being of critical importance given the urgent need to abate climate change. The near-term profitability of this climate mitigation opportunity can accelerate deployment of CCS in general and economically incentivize research in support of this goal. The paper also discusses fiscal and regulatory challenges as well as the imperative need to scale up.	Accepted. We have provided an update on this with an assessment of the recent literature and the amount of net sequestered CO2 using EOR.	Katherine Romanak	The University of Texas at Austin	United States of America
17535	42	29	42	40	Nuñez-López, V., and Moskal, E., 2019, Potential of CO2-EOR for near-term decarbonization: Frontiers in Climate, 14 p., http://doi.org/10.3389/fclim.2019.00005 https://www.frontiersin.org/articles/10.3389/fclim.2019.00005/full	Accepted. We have provided an update on this with an assessment of the recent literature and the amount of net sequestered CO2 using EOR.	Katherine Romanak	The University of Texas at Austin	United States of America
29441	42	30	42	32	Enhanced gas recovery has not been part of most previously cited literature. Enhanced gas recovery using CO2 is not as mature, or well cited in the literature. Suggest retain enhanced oil recovery but remove enhanced gas recovery.	Rejected. While enhanced gas recovery does have limited literature as compared to enhanced oil recovery, we deem it sufficient to provide some assessment in this report.	Eve Tamme	Global Carbon Capture and Storage Institute	Belgium
12369	42	33	42	35	This sentence is somewhat unclear, especially "net carbon efficiency" and "during refining and combustion" cause some confusion. E.g., does this include life cycle emissions, or is it only related to emissions during operation?	Accepted. The language has been modified to indicate life-cycle emissions.	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
18017	42	34	42	35	Clarification suggested. Should be clear this is CO2-EOR being discussed, not CCS. And should say "combustion of additional oil produced" to be clear. Also the Azzolina refernce is missing from references.	Accepted. We have made the description clearer and added the suggested citation.	Tim Dixon	IEAGHG	United Kingdom (of Great Britain and Northern Ireland)
16989	42	37	42	40	I think this sentence is unrelated to the technological status but economic aspect of CCS.	Taken into account. The section has been reorganized.	Qing YANG	Harvard University	China
16987	42	41	42	41	I suppose it refers to Table 6.7 rather than Table 6.5.	Editorial	Qing YANG	Harvard University	China
17539	42	41	42	45	67% cost reduction on 2nd generation capture from learnings from Boundary Dam project demonstrated by the Shand feasibility study - https://ccsknowledge.com/pub/documents/publications/Shand%20CCS%20Feasibility%20Study%20Public%20_Full%20Report_NOV2018.pdf and Bruce, Corwyn and Giannaris, Stavroula and Jacobs, Brent and Janowczyk, Dominika and Srisang, Wayuta, Post Combustion CO2 Capture Retrofit of Saskpower's Shand Power Station: Capital and Operating Cost Reduction of a 2nd Generation Capture Facility. 14th Greenhouse Gas Control Technologies Conference Melbourne 21-26 October 2018 (GHGT-14) . Available at SSRN: https://ssrn.com/abstract=3366401	Taken into account. We have indicated cost reductions from peer-reviewed literature.	Katherine Romanak	The University of Texas at Austin	United States of America
26211	42	41			where are 2nd and 3rd generation CCS technologies being defined?	Accepted. We have provided more details.	Sara Budinis	International Energy Agency	France
30939	42	45	42	45	Zhu et al. 2018 is not cited, as also Abanades in the next table	Taken into account. These changes will be made.	Pietro Bartocci	University of Perugia	Italy
16991	43	1	43	2	Table 6.7 has cited the reference, which sums up the various CCS technologies from the scale and technological readiness levels (TRL). But the meanings of TRL 1 to TRL 9 are not clarified in this table.	Accepted. We have provided a reference to clarify this.	Qing YANG	Harvard University	China
4879	43	2	43	2	The reference Abanades et al. 2019 is missing from the reference list / is not defined. The same applies to the SRCCS (whose acronym is also not defined - Special Report on CCS)	Taken into account. These changes will be made.	Patrick Lamers	National Renewable Energy Laboratory	United States of America
12373	43	2	43	3	Table 6.7 Absorption-Chemical-post-combustion should write "Demonstrated at two commercial facilities Boundary Dam since 2015 and Petra Nova since 2017 with capacity of 1 and 1.6 Mt CO2/y respectively"	Accepted. We have made this change.	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
16993	43	4	43	10	Because the economic of CCS would be largely influnced by the carbon price/tax or carbon trading. Thus it is suggested that this part also should discussed it so as to make a comprehensive knowleadge for CCS's economic in future.	Taken into account. Carbon pricing and trading have been discussed elsewhere in the chapter.	Qing YANG	Harvard University	China
16997	43	4	44	2	These parts discusses the economic of CCS plants including coal and gas. However, there are also several existing bioenergy plants (e.g. bio-ethanol with CCS, BECCS) around the world. This part should not only be restricted in fossil fuel with CCS, but shoud be discussed in a depth and conprehensive aspect.	Taken into account. This section discusses CCS more generally. 6.4.2.6 discusses bioenergy.	Qing YANG	Harvard University	China

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
26213	43	4			the lack of a sustainable business model is the pressing issue with CCS, rather than the cost (anything can be expensive, but what matters is the value of the source of revenues, which is missing for CCS)	Taken into account. We agree with the comment but restrict the discussion here due to page constraints.	Sara Budinis	International Energy Agency	France
4885	43	5	44	32	This text is inadequately written. It needs editing for language and content. It fails to highlight the key messages appropriately. CCS is too critical component of a component for this Chapter and the overall climate context to be treated like an afterthought.	Taken into account.	Patrick Lamers	National Renewable Energy Laboratory	United States of America
4883	43	6	43	7	revise sentence	Accepted. Sentence has been revised	Patrick Lamers	National Renewable Energy Laboratory	United States of America
12379	43	7	43	7	Please refer to Table 6.8	Taken into account.	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
16995	43	7	43	7	I suppose it refers to Table 6.8 rather than Table 6.	Editorial	Qing YANG	Harvard University	China
23927	43	9	43	11	The classification of biomass for bioenergy is very uncommon: manure is a typical agricultural residue. Additionally there are also biomass ressources, which are nor related to agriculture nor to forestry, such as biomass from parks, nature protection ares, road side green. Also sewage sludge is important in some countries. I propose to use the classification of Brosowski, A., Thrän, D., Mantau, U., Mahro, B., Erdmann, G., Adler, P., Stinner, W., Reinhold, G., Hering, T., Blanke, C., (2016): A review of biomass potential and current utilisation – Status quo for 93 biogenic wastes and residues in Germany. Biomass Bioenerg. 95 , 257 - 272	Taken into account. Discussion of biomass has been carried out in 6.4.2.6.	Stefan Majer	German Biomass Research Centre - DBFZ	Germany
31433	43	11	43	14	You may integrate an estimated CO2 price, when CCS is becoming profitable (around $70??)	Taken into account. Carbon pricing and trading have been discussed elsewhere in the chapter.	Patrick Jochem	German Aerospace Center (DLR)	Germany
20753	43				Table6.7. the meaning of the score of TRL should be explained .	Accepted.Meaning explained	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	China
5717	44	2	44	2	Rubin's paper is a little out of date now, particularly since Bounday Dam has come on stream. The particular figure of ire is the 44 % increase in fuel requirement - this must be an outlier, with an extremely low base efficiency and a bad CCS technology. Essentially, no project with 44 % increase in fuel burn will be viable, and it is unrepresentative of the technology as a whole.	Rejected. We have provided our assessment based on overall assessment of the literature.	paul fennell	Imperial College	United Kingdom (of Great Britain and Northern Ireland)
15709	44	2	44	2	Table 6.8 is difficult to understand. The second row seem to be of reference costs without CCS per MWh; why isn't there also a row with costs for CCS included? If of use, a review of incremental CCS costs for supercritical coal and NGCCGT plants is provided in Table 1, page 5 of Bataille, C., N. Melton and M. Jaccard. 2015. Policy uncertainty and diffusion of carbon capture and storage in an optimal region. Climate Policy 15(5): 565-582 doi: 10.1080/14693062.2014.953905	Taken into account. The abbreviations have been accepted.	CHRISTOPHER BATAILLE	IDDRI.ORG/SIMON FRASER UNVIERSITY	Canada
9545	44	2	44	3	Table 6.8 is confusing and incomplete. The title and column headers suggest numbers for plants WITH CCS, but the row on LCoE is for "reference plants WITHOUT CCS" and no indication for cost of CCS (investment, operation, fuel, storage, LCoE) is included.	Taken into account. The abbreviations have been accepted.	Tom Kram	PBL (Fellow)	Netherlands
12375	44	2	44	3	Table 6.8 Abbreviations should be explained	Accepted. Text modified	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
9617	44	4			Something is missing in the sentence "It must be noted that few previous years…"	Accepted. The text has now been revised.	David Sholl	Georgia Institute of Technology	United States of America
4457	44	15	44	16	"It has been anticipated that reductions in CCS costs may lead to large-scale commercialization, which again can give rise to reduced prices through technological learning". Is there any evidence of learning curve effects for CCS technologies or is this only a claim by the authors?	Accepted. Additional literature has been provided on this.	Leonardo Barreto	Austrian Energy Agency	Austria
4887	44	17	44	17	Do you mean Integrated assessment models? Or what type of integrated assessments? Of the energy system?	Accepted. We mean IAMs.	Patrick Lamers	National Renewable Energy Laboratory	United States of America
32453	44	21	44	32	The focus should always be on CCUS (and not just CCS). California's Low Carbon Fuel Standard currently encourages CCUS. The program attempts to lower emissions from the transportation sector by requiring producers of petroleum-based fuels to lower the carbon intensity of their fuels (measured in grams of CO2 emitted per MJ of fuel). One of the methods of compliance is for producers to implement CCS at refineries and oil fields.	Accepted. The differences between CCS and CCU have been clearly outlined with a much greater description of CCU than FOD.	Durwood Zaelke	Institute for Governance & Sustainable Development	United States of America
4889	44	24	44	25	Wrong, the 45Q credit is for CCS only. It does not aim to incentivize DACCS - albeit it could provide incetives to this technology it was mainly aimed to help fossil plants retrofit CCS technologies and thus help extend their run times.	Rejected. 45Q tax credit now applies to direct air capture as well	Patrick Lamers	National Renewable Energy Laboratory	United States of America
17541	44	24	44	25	To be complete on new incetives, an additional international economic driver for Direct Air capture is the new Carbon Capture and Sequestration Protocol Under the California Low Carbon Fuel Standard https://ww2.arb.ca.gov/resources/documents/carbon-capture-and-sequestration-protocol-under-low-carbon-fuel-standard	Accepted. This has been added.	Katherine Romanak	The University of Texas at Austin	United States of America
26215	44	25			I suggest to stick with ether NET or CDR nomenclature (with a personal preference towards the second one)	Accepted. CDR is used throughout the report.	Sara Budinis	International Energy Agency	France
31821	44	26	44	26	Similar to nuclear, isn't the most key challenge economics even more than public acceptance?	Noted. There are several challenges to CCUS and it is difficult to pinpoint the most pertinent.	Ashok Sreenivas	Prayas (Energy Group)	India

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
12377	44	26	44	28	Please consider to include a reference to this statement, if available. Especially regarding the last part of the sentence "the tendency to reduce investments towards renewable".	Taken into account. The text has now been revised.	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
18019	44	28	44	28	Reducing investment in renewables - I am not aware of any evidence anywhere of this, and no evidence/reference is provided here.	Taken into account. The text has now been revised.	Tim Dixon	IEAGHG	United Kingdom (of Great Britain and Northern Ireland)
17537	44	28	44	31	The statement "Moreover, technological challenges that have become better quantified include: ensuring reliable sequestration by proper regulation, failing which leakages may be substantial both during transportation and storage as quantified by (Alcalde et al. 2018); - the statement does not seem supported by the refernce cited. As written it is also misleading as even in areas without regulation there have been no "significant leakages"	Accepted. The text has now been revised.	Katherine Romanak	The University of Texas at Austin	United States of America
5715	44	30	44	30	CO2 will NOT leak during transport and storage unless it is being done incredibly badly. Of course regulation is important, but it is important for all technologies. Look back to the IPCC special report on CCS. This is a straw man argument.	Accepted. The text has now been revised.	paul fennell	Imperial College	United Kingdom (of Great Britain and Northern Ireland)
18021	44	30	44	30	I challenge the "leakages may be substantial during transport and storage". There is no evidence for this, and the Alcade paper aims to show the opposite, even with an unregulated and leaky site the worst case scenario would be more than 78% retained over 10,000 years.	Accepted. The text has now been revised.	Tim Dixon	IEAGHG	United Kingdom (of Great Britain and Northern Ireland)
29455	44	30	44	30	The following sentence does not make sense: "failing which leakages may be substantial both during transportation and storage as quantified .."	Accepted. The text has now been revised.	Eve Tamme	Global Carbon Capture and Storage Institute	Belgium
11355	44	30	44	31	'by (Alcade etal., 2018)' should be 'by Alcade et al., 2018'	Accepted. The text has now been revised.	PINAKI SARKAR	CSIR-CENTRAL INSTITUTE OF MINING AND FUEL RESEARCH	India
26217	44	30			on leakages: we could say the same about any process and fluid e.g. transport and storage of natural gas. It should go without saying that proper transport and storage procedures and regulations are needed	Accepted. The text has now been revised.	Sara Budinis	International Energy Agency	France
45445	44				Table 6.8 provides very good overall information for basic questions on cost and performance of CCS	Noted.	Girija Parthasarathy	Thermo King	United States of America
27939	45	1	48	33	Please clarify that BECCS has many of the same problems associated 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), as described in https://web.stanford.edu/group/efmh/jacobson/Articles/I/BiomassVsWWS.pdf	Accepted. The report has been added to the section dealing with BECCS skeptisims	Mark Jacobson	Stanford University	United States of America
4895	45	1	49	3	Is this subchapter a suitable place to deal with BECCS? Bioenergy is a cross-cutting issue (AFOLU, systems integration, etc.) and should be addressed coherently across the AR6. Since the AR5 projections for BECCS, the topic has also gathered significant public attention - and this section will be heavily scrutinized. The BECCS subchapter starts very weak and while it improves towards the end (with better writing, justification, etc.), it should be discussed whether additional experts could help improve the text. Bioenergy has been addressed quite well in Chapter 7.5.5.	Noted. Text modified and linkage has been created with the section 6.4.2.5 on CCUS	Patrick Lamers	National Renewable Energy Laboratory	United States of America
4905	45	1	49	3	Pls compare Chapter 6.4.2.6 with Chapter 7.5.5 for information on BECCS (e.g., p. 7-54 lines 49ff), reconcile respective estimates, and update Chapter 6.4.2.6	Accepted. Text modified and linkage has been created with the section 6.4.2.5 on CCUS and other chapters.	Patrick Lamers	National Renewable Energy Laboratory	United States of America
27267	45	2	45	2	should refer to the glossary on biomass, bioenergy is energy derived from biomass or its metabolic by-products. Organic matter is wrong, if, then it should be "recent organic matter" to separate it from fossilized organic compounds.	Accepted., text changed	Karlheinz Erb	Institute of Social Ecology, Univ. of Natural Resources and Life Sciences Vienna	Austria
15629	45	2	47	34	It seems two different people write this section and there is no integration of the writing	Accepted. Text modified.	Cheah Singfoong	Independent consultant, formerly more than 10 years with the National Renewable Energy Laboratory, USA	United States of America
26219	45	2			what about bioenergy from waste e.g. municiapl or industrial? It should be included as well	Accepted. Text modified.	Sara Budinis	International Energy Agency	France
2153	45	9	45	11	Which type is algae?	Accepted, text modified.	Amy Townsend-Small	University of Cincinnati	United States of America
4891	45	9	45	11	This appears to be an arbitrary separation into four categories, e.g., energy crops usually do not include food crops (in some IAMs they do - but that is controversial as most bottom-up modelers do not agree to this). I suggest to make use of existing IPCC literature, e.g., the SRREN, SRCCL, and the AR5.	Accepted., classification has been updated	Patrick Lamers	National Renewable Energy Laboratory	United States of America
16999	45	9	45	11	"…(3) agricultural residues (harvesting residue, processing residue and food waste)", but in some reference the food waste belongs to municipal waste. Thus this sentence is not strict.	Accepted. Text modified to include residues and municipal solid waste in the same category	Qing YANG	Harvard University	China
23915	45	9	45	11	there are other biomass residues, e.g. landscape, etc.. What about the cascading use, is it considered in the potential? Is that a theorethical potential?	Noted. We don't know if models consider landscaping residues per se in their potential estimates, but this seems a pretty small component, especially given the huge variability across estimates.	Stefan Majer	German Biomass Research Centre - DBFZ	Germany

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
4897	45	12	45	13	Wrong, and if you indeed think so, pls provide respective references	Accepted. Text modified.	Patrick Lamers	National Renewable Energy Laboratory	United States of America
17001	45	12	45	13	"Although almost all studies on the bioenergy potential are based on FAO statistics..." actually most of calculations for bioenergy potential are based on lots of sources, such as the national statistics, net primary productivity (NPP) data, simulations. Thus this sentence is not strict and misleading.	Accepted. Text modified.	Qing YANG	Harvard University	China
27269	45	12	45	20	The text, with an upper boundary of 1100 EJ/yr (please add yr-1 to the unit), is not in line witjh the table, that only goes to 600. Furthermore, the para should make clear that upper boundary (>600EJ/yr) potential calculation are not mainstream but reflect over-optimistic technical potentials. The passages are, as formulated, seemingly not in line with box 11.5, ch11 in AR5. See also doi 10.1088/1748-9326/ab6c2e for an overview over studies. Box 6.10 will be critical here.	Accepted. The text has been modified with linkages to the relevant portions of the chapter	Karlheinz Erb	Institute of Social Ecology, Univ. of Natural Resources and Life Sciences Vienna	Austria
4893	45	12	45	24	This needs editorial changes and more references to back up the ranges. Further, several recent studies have provided specific ranges for the potentials and sub-categories. E.g., Roe S, et al., 2019, Nature Climate Change, 9, 817-28.	Accepted. Several references have been added here.	Patrick Lamers	National Renewable Energy Laboratory	United States of America
4899	45	13	45	15	Yes, but there are also uncertainties for life in general. What are you trying to say? What are the ranges? Total potential? Over time? What scales?	Accepted. Text modified.	Patrick Lamers	National Renewable Energy Laboratory	United States of America
11357	45	17	45	17	consider correction in : '0 EJ/a up to more than 1150 EJ/ '	Noted. Consistent with revised text	PINAKI SARKAR	CSIR-CENTRAL INSTITUTE OF MINING AND FUEL RESEARCH	India
1221	45	17	45	18	Provide unit	Accepted. Text modified.	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
15627	45	17	45	18	Is the estimate on existing bioenergy potential also from IEA 2007?	Noted. It is from a number of different sources. Several additional references have now been provided.	Cheah Singfoong	Independent consultant, formerly more than 10 years with the National Renewable Energy Laboratory, USA	United States of America
19865	45	17	45	18	Statements at Rows 17&18 'Existing potential estimates range from 0 EJ/a up to more than 1,550 EJ/a ' and at Rows 28&29 'It is estimated that bioenergy contributed in 2017 to 12.4% (46EJ) to the total final energy consumption' are conflicting.	Accepted. I think this is more clear now, the estimates are for 2050	Ghulam Rasul Athar	Pakistan Atomic Energy Commission	Pakistan
26221	45	17			More recent sources are available e.g. Technology Roadmap: Delivering Sustainable Bioenergy (IEA Bioenergy, 2017)	Noted. This has not been discussed due to space constraints.	Sara Budinis	International Energy Agency	France
16525	45	18			1550EJ should be 1550 EJ/a	Accepted. Text modified.	Lining WANG	Economics and Technology Research Institute, CNPC	China
4901	45	21	45	21	Needs citation	Accepted. Several references have been added here.	Patrick Lamers	National Renewable Energy Laboratory	United States of America
4903	45	21	45	23	There are also accepted general descriptions of biomass potentials from geophysical/theoretical >> technical >> economical/market >> sustainable/ecological >> socially acceptable (all nested within each other). Pls see for instance Batidzirai et al. 2012, Renewable and Sustainable Energy Reviews 16, pp 6598–6630.	Accepted. Text modified.	Patrick Lamers	National Renewable Energy Laboratory	United States of America
4459	45	21	45	24	Are there any figures available for bioenergy potentials taking into account sustainability and GHG emissions savings criteria?	Accepted. Several references have been cited.	Leonardo Barreto	Austrian Energy Agency	Austria
28877	45	21	46	26	You telling us that, "Based on key assumptions, three main levels of 24 potential have been estimated…" then you show the table 6.9. But the there is no further explanation what's for those key assumption are for. As a reader, I feel left hanging.	Accepted. Several references have been added here.	Marissa Malahayati	National Institute for Environmental Studies	Japan
20279	45	25	25	25	"increases in food-crop yields will outpace demand for food, with the result that an area of high yielding agricultural land the size". This statement seems to be unreliable and out of date. The curent experience with substantively decreased crop yields recently reported in US and Africa in recent years and the relationship to land degradation. drought and kill, overfertilise and grow policies, over reliance on 9 main crops and increased disease vulnerablity etc., does not correlate with this statement. (UNEP GEO Global Assessment (2019).and many other references within - "Kill and grow" are the words of teh Danpne CEO for the Monsanto Feed the World model.	Accepted. Text modified.	Paul Dumble	Paul's Environmt Lentd	United Kingdom (of Great Britain and Northern Ireland)
23917	45	27	45	27	what is modern biomass? Everything, which is not traditional? And what is modern bioenergy? Only depends on the biomass used or also on the conversion technology and ist application?	Accepted. Text modified.	Stefan Majer	German Biomass Research Centre - DBFZ	Germany
15631	45	27	45	30	This paragraph can be moved to near top of the page to form part of the introduction of what bioenergy encompasses	Accepted. Text modified.	Cheah Singfoong	Independent consultant, formerly more than 10 years with the National Renewable Energy Laboratory, USA	United States of America
23929	45	27	45	30	The definition of traditional biomass is not very clear and is only provided in a foodnote. I propose to have it in the paragraph	Accepted. Text modified.	Stefan Majer	German Biomass Research Centre - DBFZ	Germany

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
39295	45	42	45	42	Is geophysical really the good term ? The paragraph talks more about georessources than geophysics.	Accepted. Definition clarified and moved up. Left it as footnote, I don't think it makes any difference	Bruno Gavazzi	UMR7516 Institut de Physique du Globe de Strasbourg (CNRS/Université de Strasbourg	France
19863	45		45		Reference (Source) is missing for Table 6.9.	Rejected. This is consistent with terminology.	Ghulam Rasul Athar	Pakistan Atomic Energy Commission	Pakistan
23931	46	3	46	4	The figure should also differ between "non-biomass-renewable" and "non-biomass-fossil" to underline the statement in line	Noted. This has not been discussed due to space constraints	Stefan Majer	German Biomass Research Centre - DBFZ	Germany
23933	46	6	46	10	The very bad energy efficiency of about 10% is also a substantia problem and should be named in a chapter which also adresses potentials and availabilits of biomass.	Accepted. Text modified.	Stefan Majer	German Biomass Research Centre - DBFZ	Germany
32141	46	6	46	21	This is a nice section on Traditional biomass. I enjoy reding it, but at the same time, I do not understand why the authors are note mentioning the REDD+ and NDC references on Traditional biomass. IN this section and other part of the chapter, it will be good to highlight the negative effect that traditional biomass collection is causing to tropical forest ecosystem (particularly in Africa, and specifically in the Congo Basin). It will be good to mention the fact that many REDD+ initiatives in the continent (Africa) consider biomass collection as one of the main direct drivers of forest destruction. Many of the REDD+ projects thus insert biomass Energy considerations as one of the key responses… we probably need to learn from these traditional biomass considerations in REDD+ project ant start exploring some lessons that may be useful when framing the second generation of NDCs.	Accepted. Text modified.	Denis Jean Sonwa	CIFOR (Center for International Forestry Reseacrh)	Cameroon
41395	46	6	46	21	This is the only place where I have found a full paragrapgh of text on traditional biomass. Traditional biomass is a large and important part of global energy supply and it deserves much more attention. This is the fuel supply of billions of people and its lack of attention in research and policy should not be reiterated by the IPCC. There is research to analyse and cite! In particular, problems and solutions within the biomass sector need to be distinguished; sustainable fuel supply (through agroforestry, plantations, forest management etc.), as well as cleaner and more efficient conversion technologies (cookstoves). Direct fuelwood use and charcoal must be distinguished and the charcoal supply chain explained. The large and growing charcoal demand in Sub-Saharan Africa is very important and deserves much more attention, here or in chapter 7.	Accepted. Text modified.	Cecilia Sundberg	Swedish University of Agricultural Sciences	Sweden
41397	46	13	46	17	"many studies" is mentioned without any citations. Do check literature by authors such as R. Bailis, M. Iiyama, M. Njenga here.	Accepted. Several references have been added here.	Cecilia Sundberg	Swedish University of Agricultural Sciences	Sweden
15633	46	20	46	20	Clarify what "medium confidence" really mean	Taken into account. Please refer to the executive summary for this nomenclature	Cheah Singfoong	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
32455	46	21	46	26	BECCS is not carbon negative in the near-term because bioenergy leaves a carbon deficit for several decades to a century—far longer than the window of a decade or two available for slowing feedbacks and avoiding crashing through the 1.5C guardrail. See, e.g., IPCC AR5 WG III (2014) 11.13.4 GHG emission estimates of bioenergy production systems ("The combustion of biomass generates gross GHG emissions roughly equivalent to the combustion of fossil fuels. If bioenergy production is to generate a net reduction in emissions, it must do so by offsetting those emissions through increased net carbon uptake of biota and soils…Hence, the total climate forcing of bioenergy depends on feedstock, site-specific climate and ecosystems, management conditions, production pathways, end use, and on the interdependencies with energy and land markets…For example, in the specific case of existing forests that may continue to grow if not used for bioenergy, some studies employing counterfactual baselines show that forest bioenergy systems can temporarily have higher cumulative CO2 emissions than a fossil reference system (for a time period ranging from a few decades up to several centuries"). Subsequent analysis since AR5 further strengthens the case that bioenergy is not carbon neutral in the critical next decade or two. Danielle Venton, Core Concept: Can bioenergy with carbon capture and storage make an impact?, PNAS (2016); 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.	Accepted. Text modified.	Durwood Zaelke	Institute for Governance & Sustainable Development	United States of America
32455	46	21	46	26	Comment continued: 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."). In addition, the CCS part of BECCS has not been demonstrated at scale or at acceptable cost, nor has it won over the support it would need from the public. See Gregory Nemet et al., Negative emissions—Part 3: Innovation and upscaling, Environ. Res. Lett. (May 2018); European Academies Science Advisory Council, Negative emission technologies: What role in meeting Paris Agreement targets? (Feb 2018) ("CCS plans in Europe have been shelved so that whatever experience is being gained globally is outside Europe. The loss in momentum in implementing CCS technologies not only has serious implications for mitigation pathways, but also one of the most commonly cited NETs [negative emissions technologies] (BECCS) assumes the availability of cost effective 'off-the shelf' CCS, while another (direct air capture) relies on the widespread availability of CO2 storage. At present, economic incentives for deploying CCS are inadequate (whether through the very low carbon price or targeted government support), while those for NET development are lacking."); Andersen & Peters, The Trouble with Negative Emissions, Science (Oct 2016). One study estimates that current rate of increase in CCS is 100 times lower than needed to meet the 2C target. See Haszeldine et al. (April 2018), Negative emissions technologies and carbon capture and storage to achieve the Paris Agreement commitments, Philosophical Transactions of the Royal Society. Thus, BECCS should not be presented as a viable CDR strategy.		Durwood Zaelke	Institute for Governance & Sustainable Development	United States of America
44605	46	22	46	26	You shouldn't ignore the strand of the literature that shows that bioenergy systems aren't necessarily carbon neutral (depending on timeframes and LCA scopes). It still can be net negative if combined with CCS	Accepted. Text modified.	Oliver Geden	German Institute for International and Security Affairs	Germany
15635	46	23	46	24	Bioenergy is not entirely zero emission. If energy source is needed to transport or convert it to liquid fuel, for example, then that energy needs to be in the overall accounting	Accepted. Text modified.	Cheah Singfoong	Independent consultant, formerly more than 10 years with the National Renewable Energy Laboratory, USA	United States of America
20613	46	23	46	24	The argument that bioenergy is, in principle, a zero-emission technology has to be supplemented with caveats. Concerning bioenergy produced from energy crops, there is significant literature that land-use change emissions may be significant in many cases rendering bioenergy worse than fossil fuel alternatives. Concerning residues and forestry, the GHG impact is lower but still extremely uncertain.	Accepted. Text modified.	Vassilis Daioglou	Copernicus Institute of Sustainable Development	Netherlands

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
17003	46	23	47	24	"The tendency of bioenergy…make it a zero-emission technology." But in fact from life-cycle aspect, the bioenergy would not cause zero carbon emissions considering the upstream materials. Moreover, it is believed that there have been some bioenergy technologies (e.g. corn ethanol production) would cause more carbon emissions compared with such as natural gas systems. Thus this sentence is not strict and scientific.	Accepted. Text modified.	Qing YANG	Harvard University	China
15637	46	24	46	24	Clarify what "this emitted carbon" means. Do you mean "carbon emitted during biomass conversion/utilization"?	Accepted. Text modified.	Cheah Singfoong	Independent consultant, formerly more than 10 years with the National Renewable Energy Laboratory, USA	United States of America
17005	46	24	47	26	According to current research, bioenergy with CO2 capture and storage (BECCS) and biochar would be two improtant negative emission technology for 1.5 celsius target. Moreover biochar technology has less technological, economic, environmental and social problems in near future compared with BECCS technology. Thus it is suggested to make a short discription for both of them rather than just BECCS.	Noted. Biochar is not discussed here due to space constraints.	Qing YANG	Harvard University	China
15639	46	25	46	25	Would the CO2 capture and storage technology potentially make it positive emission if large amount of energy is needed to capture the CO2?	Accepted. Text modified.	Cheah Singfoong	Independent consultant, formerly more than 10 years with the National Renewable Energy Laboratory, USA	United States of America
15641	47	1	47	2	What is the current estimated cost for BECCS now?	Accepted. Text modified.	Cheah Singfoong	Independent consultant, formerly more than 10 years with the National Renewable Energy Laboratory, USA	United States of America
15649	47	1	47	3	References or justification (logical reasoning) is needed to explain why the cost would decrease 30-50% in the next three decades. Could the decrease be more or perhaps less than 30-50%?	Accepted. Text modified.	Cheah Singfoong	Independent consultant, formerly more than 10 years with the National Renewable Energy Laboratory, USA	United States of America
34163	47	1	47	27	Although the paragraph mentions EROI for some bioenergy variations, it doesn't give any general figure (arround 1.3 ?) and does not explain it depth why this is a problem for this technology (highly space intensive) [suggestion ENSEEIHT INP]	Accepted. Text modified.	Antoine BONDUELLE	Climate Action Network France	France
11359	47	4	47	4	'Co-firing of various technologies'- consider correction	Accepted. Text modified.	PINAKI SARKAR	CSIR-CENTRAL INSTITUTE OF MINING AND FUEL RESEARCH	India
26267	47	4	47	7	I would like to add the possibility of combined heat and power (CHP) to reduce the energy penalty of carbon catpture both in CCS and BECCS applications as waste heat from capture processes can be recovered as usable energy products. Se Levihn et al (2019). https://doi.org/10.1016/j.egyr.2019.09.018	Accepted. Text modified.	Levihn Fabian	KTH - Royal Institute of Technology	Sweden
15643	47	7	47	9	The text in the figure is too small. The figure is also very low resolution, impossible to read.	Accepted. Figure has been removed	Cheah Singfoong	Independent consultant, formerly more than 10 years with the National Renewable Energy Laboratory, USA	United States of America
17243	47	8	47	11	The figure is not legible (printing quality is poor) and the different options shown need to be explained. The abbreviations - as far as they can be guessed - are not known to many readers.	Accepted. Figure has been removed	Joachim Rock	Thuenen-Institute of Forest Ecosystems	Germany
17007	47	9	47	11	I suggest use the figure in reference [1], which shows the economic for BECCS, biochar and traditional bioenergy technology. [1] Woolf D , Lehmann J , Lee D R . Optimal bioenergy power generation for climate change mitigation with or without carbon sequestration[J]. Nature Communications, 2016, 7:13160.	Accepted. Modified.	Qing YANG	Harvard University	China
25071	47	15	47	15	Delete "potential"	Accepted. Text modified.	Eleni Kaditi	Organization of the Petroleum Exporting Countries (OPEC)	Austria
38071	47	15			"potential' has been written twice	Accepted. Text modified	Craig Jamieson	Straw Innovations Ltd	Philippines

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
5719	47	20	47	20	The argument that less efficient plants will result in more CO2 being sequestered may be correct on any single plant, but the plant as a whole will be less profitable (since it will be producing less electricity). The electricity production subsidises the CO2 removal, and so when expanded to consider whether or not BECCS as a whole would be likely to be developed, it makes no sense to say that less efficient plants capture more CO2 - they just won't be built. The reductio ad absurdum here is to consider a plant that produces zero electricity and only captures CO2. Why go to all of the bother of using a power station to convert wood to CO2 in this case? You can do better things with the wood.	Rejected. Our assessment here is based on the coverage in peer-reviewed literature.	paul fennell	Imperial College	United Kingdom (of Great Britain and Northern Ireland)
12381	47	27	47	27	Abbreviation of EROI should be given the first time it is used	Accepted. Text modified.	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
32457	47	28	47	34	Even if BECCS were net zero or negative in the relevant next couple of decades, which it is not, using BECCS to draw down the between 2 and 10 Gt CO2 annually that is mentioned in IAM reports would require the dedication of land equivalent to the size of India, and possibly even double this amount, to support biomass production, introducing daunting logistical issues. See Anderson K. & Peters G. (2016) The trouble with negative emissions, SCIENCE 354:182–183, 183 ("Moreover, the scale of biomass assumed in IAMs—typically, one to two times the area of India—raises profound questions about carbon neutrality, land availability, competition with food production, and competing demands for bioenergy from the transport, heating, and industrial sectors. The logistics of collating and transporting vast quantities of bioenergy—equivalent to up to half of the total global primary energy consumption—is seldom addressed. Some studies suggest that BECCS pathways are feasible, at least locally, but globally there are substantial limitations. BECCS thus remains a highly speculative technology.").	Accepted. Text modified.	Durwood Zaelke	Institute for Governance & Sustainable Development	United States of America
8893	47	28	48	14	I suggest to mention that burning biomass produces CO2 and air pollution. The best use of forestry is lumber and durable woods.	Accepted. Text modified	Michel SIMON	Vice Président SFENRAL	France
4461	47	29	47	30	If land use and water-use estimates for BECCS are orders of magnitude higher than conventional energy generating technologies, how are they compatible with energy efficiency and resource efficiency principles and criteria?	Accepted. Text modified.	Leonardo Barreto	Austrian Energy Agency	Austria
18699	47	31	47	34	We will need to harmonize the resource use estimates for fertilizers, land and water as presented by several papers to units of kg/kWh ...' - this looks like an internal note rather than the final sentence	Accepted. Text modified	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
30941	48	1	48	2	figure 6.20 the meaning of biochar is not explaine in the text.	Accepted. Text modified	Pietro Bartocci	University of Perugia	Italy
38073	48	1			Figure 6.20 requires a key to explain what the acronyms are, e.g. "EW" and "SCS"	Accepted. Figure has been removed	Craig Jamieson	Straw Innovations Ltd	Philippines
41379	48	2	48	2	This figure shows biochar as a negative energy CDR technology, i.e. there is energy production through biochar-bioenergy production. This should be mentioned in the text, e.g. page 105, line 16-18. See Homagain et al 2015 (cited in this chapter), Azzi et al 2019 doi: 10.1021/acs.est.9b01615	Accepted. Text modified	Cecilia Sundberg	Swedish University of Agricultural Sciences	Sweden
23935	48	2	48	26	Integrated assessment should also inlude social and systemic aspects. There has been an holistic assessment of BECCS for Germany which also considers the effort for transformation, showing that especially the transformation form small to large scale systems can lead to problems in acceptance (see: https://www.dbfz.de/fileadmin/user_upload/Download/Extern/ESYS_Analyse_Biomasse.pdf).	Taken into account. Please refer to the section 6.7.7 for this discussion	Stefan Majer	German Biomass Research Centre - DBFZ	Germany
4463	48	4	48	8	Sustainability and GHG emission savings criteria shuld be	Noted but we are unable to understand the comment	Leonardo Barreto	Austrian Energy Agency	Austria
32459	48	4	48	14	BECCS is not carbon negative in the near-term because bioenergy leaves a carbon deficit for several decades to a century—far longer than the window of a decade or two available for slowing feedbacks and avoiding crashing through the 1.5C guardrail. See, e.g., IPCC AR5 WG III (2014) 11.13.4 GHG emission estimates of bioenergy production systems ("The combustion of biomass generates gross GHG emissions roughly equivalent to the combustion of fossil fuels. If bioenergy production is to generate a net reduction in emissions, it must do so by offsetting those emissions through increased net carbon uptake of biota and soils…Hence, the total climate forcing of bioenergy depends on feedstock, site-specific climate and ecosystems, management conditions, production pathways, end use, and on the interdependencies with energy and land markets…For example, in the specific case of existing forests that may continue to grow if not used for bioenergy, some studies employing counterfactual baselines show that forest bioenergy systems can temporarily have higher cumulative CO2 emissions than a fossil reference system (for a time period ranging from a few decades up to several centuries"). Subsequent analysis since AR5 further strengthens the case that bioenergy is not carbon neutral in the critical next decade or two. Danielle Venton, Core Concept: Can bioenergy with carbon capture and storage make an impact?, PNAS (2016); 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.	Accepted. References have been added here.	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
32459	48	4	48	14	Comment continued: 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."). In addition, the CCS part of BECCS has not been demonstrated at scale or at acceptable cost, nor has it won over the support it would need from the public. See Gregory Nemet et al., Negative emissions—Part 3: Innovation and upscaling, Environ. Res. Lett. (May 2018); European Academies Science Advisory Council, Negative emission technologies: What role in meeting Paris Agreement targets? (Feb 2018) ("CCS plans in Europe have been shelved so that whatever experience is being gained globally is outside Europe. The loss in momentum in implementing CCS technologies not only has serious implications for mitigation pathways, but also one of the most commonly cited NETs [negative emissions technologies] (BECCS) assumes the availability of cost effective 'off-the shelf' CCS, while another (direct air capture) relies on the widespread availability of CO2 storage. At present, economic incentives for deploying CCS are inadequate (whether through the very low carbon price or targeted government support), while those for NET development are lacking."); Andersen & Peters, The Trouble with Negative Emissions, Science (Oct 2016). One study estimates that current rate of increase in CCS is 100 times lower than needed to meet the 2C target. See Haszeldine et al. (April 2018), Negative emissions technologies and carbon capture and storage to achieve the Paris Agreement commitments, Philosophical Transactions of the Royal Society. Thus, BECCS should not be presented as a viable CDR strategy.		Durwood Zaelke	Institute for Governance & Sustainable Development	United States of America
32461	48	4	48	14	Even if BECCS were net zero or negative in the relevant next couple of decades, which it is not, converting planned new natural forests to bioenergy crops for BECCS systems could nearly wipe out the sequestration potential of BECCS. Some estimates expect BECCS to remove about 480 Gt CO2 by 2100. If bioenergy crops replaced planned new natural forests, that sequestration potential may be as low as 11 Gt CO2, delaying the time BECCS becomes carbon negative by decades. Lewis, S. et. al. (April 2019) Regenerate natural forests to store carbon, Nature, pp. 27-28. Further, emissions from land-use change to accommodate bioenergy production for BECCS could offset the carbon removed from the atmosphere by BECCS. See Anna B. Harper et al., Land-use emissions play a critical role in land-based mitigation for Paris climate targets, Nature Communications (August 2018) (""Under the modelled land-use and climate scenarios we find that the accumulated carbon removed from the atmosphere through BECCS is largely offset by initial reductions in stored land carbon. Our results suggest a land carbon sink that is twice as strong in the 2°C scenario compared to 1.5 °C (Fig. 2), irrespective of land-use scenario. This is due to both the fertilizing effect of CO2 being larger, and the growth of more high latitude vegetation in the 2°C scenario. These positive impacts on land carbon of the 2 °C scenario are partially offset by losses of carbon due to higher respiration rates at 2 °C compared to 1.5 °C."). See also Wannes Hubau, Asynchronous carbon sink saturation in African and Amazonian tropical forests, Nature (2020).	Accepted. References have been added here.	Durwood Zaelke	Institute for Governance & Sustainable Development	United States of America
9547	48	6	48	7	Why would bioenergy be logistically more challenging for BECCS? Explain or drop.	Noted. This would be the case due to additional CCUS complications discussed in 6.4.2.5	Tom Kram	PBL (Fellow)	Netherlands
42363	48	8	48	12	The message in this paragraph appears to contradict discussions in other part of the document. It fairly fits well if this paragraph message is rephrased. Yes, fossil plays role in climate mitigation by buying sometime while at the sametime increasing climate change risk as other data's in this same chapter clearly shows. Moreover, its success in achieving low-carbon energy supply also depends on the development of effective CCUS technology and relevant business, which is not showing any progress.	Accepted. Text modified	Solomon Asfaw	LUT University	Finland
15645	48	8	48	14	Include BECSS tecnologies developed have strong economy of scale dependence, which in turn requires transportation logistics to move biomass to the site. Co-location or close-location of biomass and suitable CO2 capture site may be challenging.	Accepted. Text modified	Cheah Singfoong	Independent consultant, formerly more than 10 years with the National Renewable Energy Laboratory, USA	United States of America
38075	48	9			I suggest saying :in significant detail elsewhere." then list references one after another in brackets.	Editorial	Craig Jamieson	Straw Innovations Ltd	Philippines
38077	48	13			Delete "availability"	Accepted. Text modified.	Craig Jamieson	Straw Innovations Ltd	Philippines

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
20617	48	15	48	26	A further institutional issue about bioenergy which has only gained prominence the past few years (references below), includes the implications of international trade of bioenergy in climate change mitigation scenarios. Broadly, the issues is that according to IAM projections, the main bioenergy demand regions are not the main supply regions, implying large increase in bioenergy trade. IAM comparison studeis (most prominently the recent EMF-33 study) have shown that this increase in trade is projected to grow at very high rates (greater than 1% per year), to levels similar to current trade in fossil fuels. This raises serious concerns about the feasibility of these scenarios concerning institutional constraints (quality standards, health & safety concerns, availability of infrastructure). Interestingly, these studeis also show the increased trade of bioenergy in mitigation scenarios does not lead to energy security issues since bioenergy supply is diverse. DAIOGLOU, V., MURATORI, M., LAMERS, P., FUJIMORI, S., KITOUS, A., BAUER, N., JUNGINGER, H. M., KATO, E., KOBERLE, A., LEBLANC, F., MIMA, S., WISE, M. & VAN VUUREN, D. in review. Implications of climate change mitigation scenarios on international bioenergy trade. Climatic Change. MATZENBERGER, J., KRANZL, L., TROMBORG, E., JUNGINGER, M., DAIOGLOU, V., SHENG GOH, C. & KERAMIDAS, K. 2015. Future perspectives of international bioenergy trade. Renewable and Sustainable Energy Reviews, 43, 926-941. JUNGINGER, M. MAI-MOULIN, T., DAIOGLOU, V. et al. 2019 The future of biomass and bioenergy deployment and trade: a synthesis of 15 years IEA Bioenergy Task 40 on sustainable bioenergy trade. Biofuels, Bioproducts and Biorefining 13 (2), 247-266	Accepted. Text modified	Vassilis Daioglou	Copernicus Institute of Sustainable Development	Netherlands
32463	48	15	48	26	BECCS is not carbon negative in the near-term because bioenergy leaves a carbon deficit for several decades to a century—far longer than the window of a decade or two available for slowing feedbacks and avoiding crashing through the 1.5C guardrail. See, e.g., IPCC AR5 WG III (2014) 11.13.4 GHG emission estimates of bioenergy production systems ("The combustion of biomass generates gross GHG emissions roughly equivalent to the combustion of fossil fuels. If bioenergy production is to generate a net reduction in emissions, it must do so by offsetting those emissions through increased net carbon uptake of biota and soils…Hence, the total climate forcing of bioenergy depends on feedstock, site-specific climate and ecosystems, management conditions, production pathways, end use, and on the interdependencies with energy and land markets…For example, in the specific case of existing forests that may continue to grow if not used for bioenergy, some studies employing counterfactual baselines show that forest bioenergy systems can temporarily have higher cumulative CO2 emissions than a fossil reference system (for a time period ranging from a few decades up to several centuries"). Subsequent analysis since AR5 further strengthens the case that bioenergy is not carbon neutral in the critical next decade or two. Danielle Venton, Core Concept: Can bioenergy with carbon capture and storage make an impact?, PNAS (2016); 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.").	Accepted. Several references have been added here.	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
32465	48	15	48	26	CCS has not been perfected at scale nor has it received social acceptability. Governance gaps exist on four key CDR issues: the scale and speed of implementation, the incentives needed to scale-up CDR, the tradeoffs between Sustainable Development Goals and CDR implementation, and the risks if CDR options are not implemented. See Climate Geoengineering Governance Initiative (C2G2), Governing large-scale carbon dioxide removal: are we ready? (2018); Gregory Nemet et al., Negative emissions—Part 3: Innovation and upscaling, Environ. Res. Lett. (May 2018); European Academies Science Advisory Council, Negative emission technologies: What role in meeting Paris Agreement targets? (Feb 2018) ("CCS plans in Europe have been shelved so that whatever experience is being gained globally is outside Europe. The loss in momentum in implementing CCS technologies not only has serious implications for mitigation pathways, but also one of the most commonly cited NETs [negative emissions technologies] (BECCS) assumes the availability of cost effective 'off-the shelf' CCS, while another (direct air capture) relies on the widespread availability of CO2 storage. At present, economic incentives for deploying CCS are inadequate (whether through the very low carbon price or targeted government support), while those for NET development are lacking."); Andersen & Peters, The Trouble with Negative Emissions, Science (Oct 2016). One study estimates that current rate of increase in CCS is 100 times lower than needed to meet the 2C target. See Haszeldine et al. (April 2018), Negative emissions technologies and carbon capture and storage to achieve the Paris Agreement commitments, Philosophical Transactions of the Royal Society.	Accepted. Text modified.	Durwood Zaelke	Institute for Governance & Sustainable Development	United States of America
32467	48	15	48	26	Note also the environmental movement backlash against BECCS. See Anderson K. & Peters G. (2016) The trouble with negative emissions, SCIENCE 354:182–183.	Accepted. Text modified.	Durwood Zaelke	Institute for Governance & Sustainable Development	United States of America
20615	48	16	48	20	There is a paper under review in Climatic Change (reference below), as part of the EMF-33 special issue of bioenergy supply and demand in climate change mitigation scenarios, which investigates the reasons and uncertainty around IAM bioenergy strategies. The paper provides an overview of techno-economic paramteres for bioenergy technologies, and sumarises the reasons whay different models select different bioenergy strategies (bio-power vs bio-electricity vs other renewables, timing and deployment of BECCS). The conclusions are in line with what is written in these sentences, but with cleare technical insight into the IAMs. Crucially, the study also reveals that there is limited sensitivity of the results to uncertainaty concerning techno-economic parameterisation. DAIOGLOU, V., ROSE, S., BAUER, N., KITOUS, A., MURATORI, M., SANO, F., FUJIMORI, S., GIDDEN, M., KATO, E., KERAMIDAS, K., KLEIN, D., LEBLANC, F., TSUTSUI, J., WISE, M. & VAN VUUREN, D. in review. Bioenergy technologies and climate change mitigation pathways: Results from the EMF33 study. Climatic Change.	Accepted. Text modified.	Vassilis Daioglou	Copernicus Institute of Sustainable Development	Netherlands
6037	48	26	48	26	Incomplete explanation for '… which can be connected to 6.6.8'	Accepted. Text modified.	SAIK PENG, CASEY NGO	R-SYNC TECHNICAL RESOURCES SDN. BHD.	Malaysia
17247	48	26	48	26	Section 6.6.8 is referenced here, but no such section is included in this draft. Please correct this.	Accepted. Text modified.	Joachim Rock	Thuenen-Institute of Forest Ecosystems	Germany
15647	48	27	49	3	Why specifically BECSS in China? It seems tis section and the references favor coal in tandem with biomass in China specifically.	Accepted. Text modified.	Cheah Singfoong	Independent consultant, formerly more than 10 years with the National Renewable Energy Laboratory, USA	United States of America
5649	49	7	51	29	A pretty glaring omission from this section on Fossil Energy is the substantial recent, current, and projected future growth of the global liquefied natural gas (LNG) market. This is a very significant development in the global energy system since the release of AR5, and it absolutely merits discussion in this AR6 since it is relevant on a global scale. Of course, the GHG emissions impacts of the LNG market will depend on a complex set of competing mechanisms. On the one hand, it could substitute for coal in the power, buildings, and industrial sectors of rapidly growing economies, which would reduce emissions. On the other hand, it could lock-in substantial investments in fossil fuel infrastructure, and reduce energy prices in certain importing countries. Regardless, it is a major development for the global energy and climate landscape, and it should be discussed here.	Taken into account. 6.7.4 discusses LNG market trends.	Benjamin Leibowicz	The University of Texas at Austin	United States of America
39137	49	7	51	29	The prospect of fossil fuel in energy mix would be inserted in this section considering IPCC's 1.5 Special Report(October 2018) or it can be inserted in 6.7.4	Taken into account. 6.7.4 discusses this.	Dong-Woon NOH	Korea Energy Economics Institute	Republic of Korea
6373	49	8	49	12	It is recommended to revise and rephrase the paragraph. Fossil fuel combined CCUS has the potential to be a low or net-zero carbon system but not a zero carbon system. The emissions are not avoided but rather captured. Also, what 'limiting the economic disruption' precisely means? Please clarify and possibly support with references.	Accepted. We have reframed the language to indicate a low-carbon system.	Sciacovelli Adriano	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
31435	49	8	49	12	Please provide references here. This is not undisputed!! Furthermore, you may add a "might" in front of "limiting" in Line 11.	Accepted. We have provided the reference.	Patrick Jochem	German Aerospace Center (DLR)	Germany

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
37401	49	8	49	12	The claim that fossil fuels with CCS produce zero-carbon is wrong, as any capture system will have inefficiencies (85-90% capture rates in the literature at present). The scenario literature is clear that depedence on fossil fuels must be drastically reduced (even with CCS) in order to meet the goals of the Paris Agreement. This message is strongest in the case of coal.	Accepted. We have reframed the language to indicate a low-carbon system.	Michiel Schaeffer	Climate Analytics	Netherlands
39679	49	8	50	11	A more stringent use of the terms reserve, resource, resource base and "ultimate recoverable resources" is called for. In the first paragraph, reserves and resources are mentioned, but then mostly reserve base is discussed. Define these different concepts and be very careful with how they are used. The differences in reporting is not only from different countries, but also differs between institutions, as well as between the different fossil fuels.	Taken into account. We appreciate this comment but our discussion here is limited due to page constraints.	Simon Davidsson Kurland	Chalmers University of Technology	Sweden
44781	49	9	49	10	”On the other hand, fossil energy combined with CCUS provides a means to produce low- or zero-carbon energy” A use of fossil energy with CCUS may give low-carbon energy, but not zero-carbon energy.	Accepted. We have reframed the language to indicate a low-carbon system.	Daniel Westlén	Liberal party Swedish parliament	Sweden
34389	49	10	49	10	Replace CCUS by CCS	Rejected. We are referring to CCUS here based on section 6.4.2.5.	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
34391	49	10	49	12	CCU technologies represent key solutions to step away from fossil fuel. Current trends worldwide indicate that energy systems in this century will increasingly be based on electricity, mainly due to high technical efficiencies, comparably lower costs and the availability of prospective power-to-X technologies. These power-to-X technologies include sustainable or nonavoidable CCU (Farfan et al., 2019, Ram et al., 2019). Excess renewable energy, generated when the demands for energy are low, could potentially provide an inexpensive or even negatively priced energy supply for CO2 conversion to products. Energy storage technologies could harness excess generation that would otherwise be curtailed and make it available for use in CCU. Transport technologies are also expected to play an important role due to the likelihood that conversion technologies and sources of raw material will be in different locations (Jarvis and Samsatli, 2018). CCU technologies aim to replace fossil resources and thus they support a transformation towards renewables and extend it to industries outside the energy sector such as transport and materials (e.g. Klankermayer and Leitner, 2015). CCU as the power to stimulate the energy transition by enabling energy storage through power-to-X approaches and contribute to a circular economy by converting waste emissions into resources (IEAGHG, 2019b, Castillo-Castillo, 2019, Zhu, 2019, CCES, 2019). To reach the goal of net zero emissions, fossil fuel-based energy demand could be mainly replaced by renewable electricity (RE) (e.g. DENA, 2017, Ram et al., 2019). However, there are sectors such as aviation, shipping, heavy transportation, energy intensive industries for which hydrocarbons cannot be replaced by electricity easily, or physically not at all (e.g. Fasihi et al., 2017, Hepburn et al., 2019, SDSN &FEEM, 2019). Biofuel production is faced with resource limitations and conflicts with food production and, therefore, offers no sustainable substitute (Koizumi et al., 2015, Tomei et al., 2016). Net zero emissions could be achieved by a defossilization of the energy system, whereby carbon from fossil sources is replaced by that which is created synthetically and sustainably from CO2 with the aid of RE. These CO2-based fuels can be emission neutral and be used in the current fossil fuel-based infrastructure (DENA, 2017, Fasihi et al., 2017, Art et al., 2019, CONCAWE, 2019).	Taken into account. CCU has been discussed in detail in section 6.4.2.5.	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
34391					Comment continued: Power to fuel is the concept enabling the production of hydrocarbon fuels (e-fuels) using RE .Two types of fuels can be generated: 1) Synthetic gas (e.g. e-methane) so-called Power-to-Gas and 2) Liquid fuels (e.g. methanol, ethanol), so-called Power-to-Liquid. In both cases, CO2 and green H2 (i.e. hydrogen generated by the electrolysis of water with RE) produce e-fuel (e.g. Breyer et al., 2015, Sternberg and Bardow, 2015, Dimitrou et al., 2015, Fasihi et al., 2017, Anwar et al., 2020). These e-fuels can be stored, transported and use as such or to produce electricity again. Liquid e-fuels are easier (and relatively inexpensive) to store and transport compared to electricity. They can be kept in large-scale stationary storage over extended periods, and mobile storage in vehicle tanks, which can compensate for seasonal supply fluctuations and contribute to enhancing energy security (CONCAWE, 2019). Artz et al., 2019 has 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 in so called “Power-to-fuel” scenarios. REFERENCES: DENA, 2017, The potential of electricity-based fuels for low-emission transport in the EU: An expertise by LBST and dena (German Energy Agency)/CONCAWE, 2019: A look into the role of e-fuels in the transport system in Europe (2030–2050) (literature review), CONCAWE./Ram et al., 2019 EWG&LUT, 2019: Global Energy System Based On 100% Renewable Energy, Energy Watch Group & LUT University/Hepburn et al., 2019: The technological and economic prospects for CO2 utilization and removal, 575, 87-97/ Fasihi et al., 2017, J. of Cleaner Production, 224, 957-980/SDSN & FEEM, 2019: Roadmap to 2050 - A Manual for Nations to Decarbonize by Mid-Century, Sustainable Development Solutions Network & Fondazione Eni Enrico Mattei./ Tomei et al., 2016, Land Use Policy, 56, 320-326/Artz et al., 2019: Sustainable Conversion of Carbon Dioxide: An Integrated Review of Catalysis and Life Cycle, Assessment, Chem. Rev., 118, 2, 434-504./Dimitrou et al., 2015, Energy Environ. Sci, 8, 1775-1789./Sternberg and Bardow, 2015, Energy Environ. Sci. 8, 389–400./Anwar et al., 2020, J. of Env. Manag., 260, 110059/ Breyer et al., 2015, Energy Procedia, 73, 182-189./Koizumi et al., 2015, Renewable and Sustainable Energy Reviews, 52, 829-841./Castillo-Castillo, 2019, Policy analysis and recommendations for EU CO2 utilisation policies. In: CEST2017 15th International Conference on Environmental Science and Technology, Rhodes, Greece./ CCES, 2019: Carbon Utilization – A vital and effective pathway for decarbonization, Center for Climate and Energy Solutions./ Zhu, 2019, Clean Energy, Vol. 3, No. 2, 85–100/IEAGHG, 2019b: Exploring Clean Energy Pathways: the role of energy storage, International Energy Agency./ Klankermayer and Leitner, 2015, Science 350, 629–630/Farfan et al., 2019, J. Clean Prod., 217, 821-835./Ram et al., 2019 EWG&LUT, 2019: Global Energy System Based On 100% Renewable Energy, Energy Watch Group & LUT University./Jarvis and Samsatli, 2018, Sustain.Energy.Rev, 85, 46-48./		Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
39285	49	13	49	13	Is geophysical really the good term ? The paragraph talks more about georessources than geophysics.	Taken into account. CCU has been discussed in detail in section 6.4.2.5.	Bruno Gavazzi	UMR7516 Institut de Physique du Globe de Strasbourg (CNRS/Université de Strasbourg	France
12899	49	15	49	15	repeated word reported	Accepted. Text modified.	ASHOK NEMA	Nuclear Power Corporation of India Limited	India
31437	49	17	49	20	Shouldn’t be this reference given at the end of this paragraph (L. 20?)	Taken into account.	Patrick Jochem	German Aerospace Center (DLR)	Germany
31439	49	21	49	21	Is this a good reason “Because these are natural formations …”	Taken into account. The text has now been reframed.	Patrick Jochem	German Aerospace Center (DLR)	Germany
9549	49	21	49	22	the Figure 6.21 illustrates the very UNEVEN distribution, in particular when compared with current and projected demands. The statement that the distribution would be even because it concerns natural formations holds no water. Suggest to replace this by more relevant language, including the notion of geopolitical concerns over fossil fuel supply.	Taken into account. The text has now been reframed.	Tom Kram	PBL (Fellow)	Netherlands
28881	50	1	50	4	Make the figure more contrast and make the font bigger	Accepted.	Marissa Malahayati	National Institute for Environmental Studies	Japan
28883	50	12	50	15	Table 6.4. caption can be written as only "Unconventional oil Resources", then put Hongjun et al, 2017 and Caineng et al, 2017 on source below the table	Accepted. Text modified.	Marissa Malahayati	National Institute for Environmental Studies	Japan
31441	50	15	50	24	You may include the approach of “External Effects” here. If these are internalized, some prices for fossil fuels may differ.	Taken into account. We are constrained by page limits here to include this discussion.	Patrick Jochem	German Aerospace Center (DLR)	Germany
16527	50	18			"Figure6." should be "Figure 6.22"	Editorial	Lining WANG	Economics and Technology Research Institute, CNPC	China
20757	50	18			"Figure 6. shows that the variance in terms of resources" Figure 6.22?	Editorial	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	China
34165	50	21	50	24	EROI of those conventional fuels is falling as it becomes more cost intensive to extract them https://www.sciencedirect.com/science/article/pii/S0301421513003856 [suggestion ENSEEIHT INP]	Accepted. A discussion of decreasing EROI has been indicated.	Antoine BONDUELLE	Climate Action Network France	France
34691	50	21	50	24	It should be nonted the role of the EROI of fossil fuels to power the transition, giving less net energy for economic growth (Jordi Solé, Antonio García-Olivares, Antonio Turiel, Joaquim Ballabrera-Poy, Renewable transitions and the net energy from oil liquids: A scenarios study,Renewable Energy,Volume 116, Part A,2018,Pages 258-271,ISSN 0960-1481,https://doi.org/10.1016/j.renene.2017.09.035.)	Accepted. A discussion of decreasing EROI has been indicated.	Jordi Solé-Ollé	Spanish National Research Council (CSIC)	Spain

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
39681	50	22	50	24	The factoid that the energy return on investment (EROI) is much higher is not necessarily true and the referenced 2014 Hall et al. Paper (that appears to be missing in the reference list) is somewhat dated. It has been pointed out that not only are EROI of fossil fuels declining, but also that this comparison is faulty, as different system boundaries tend to be used for these comparisons (Brockway et al., 2019). Also, the EROI for renewables, such as photovoltaics, appears to be, not only higher than previous estimates, but also increasing with time (Koppelaar, 2017), even with the introduction of battery systems (Davidsson Kurland and Benson, 2019). Brockway, P.E., Owen, A., Brand-Correa, L.I., Hardt, L., 2019. Estimation of global final-stage energy-return-on-investment for fossil fuels with comparison to renewable energy sources. Nature Energy 4, 612–621. https://doi.org/10.1038/s41560-019-0425-z Davidsson Kurland, S., Benson, S.M., 2019. The energetic implications of introducing lithium-ion batteries into distributed photovoltaic systems. Sustainable Energy Fuels 3, 1182–1190. https://doi.org/10.1039/C9SE00127A Koppelaar, R.H.E.M., 2017. Solar-PV energy payback and net energy: Meta-assessment of study quality, reproducibility, and results harmonization. Renewable and Sustainable Energy Reviews 72, 1241–1255. https://doi.org/10.1016/j.rser.2016.10.077	Accepted. A discussion of decreasing EROI has been indicated.	Simon Davidsson Kurland	Chalmers University of Technology	Sweden
31443	50	23	50	23	Please include “most” in front of “cleaner”.	Accepted. Text modified.	Patrick Jochem	German Aerospace Center (DLR)	Germany
18701	50	24	50	24	Hall et al 2014 - reference is not found in reference section	Editorial	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
9551	51	6	51	8	Consider to use one energy unit (e.g. ZJ) consistently in Fig 6.22 to add insight in total volumes.	Accepted. Text modified	Tom Kram	PBL (Fellow)	Netherlands
20619	51	7	51	7	Figure 6.22 is very informative, however due to the different units it is difficult to extract useful insight from it. Would it be possible to add to each graph a line showing the supply curve in $/GJ (of $/kWh) vs. EJ (or TWh), indicated on a secondary axis (i.e. similar to the panel for coal)?	Accepted. Text modified	Vassilis Daioglou	Copernicus Institute of Sustainable Development	Netherlands
24339	51	7	51	7	This graph is quite difficult to read. It is hard to interpret it. Maybe add a « how to read it » in the caption.	Accepted. Text modified	Alan BURLOT	Commissariat à l'énergie atomique et aux énergies alternatives	France
17009	51	10	51	20	It is suggested to make a comparison for fossil fuels systems with CCUS with systems without CCS.	Taken into account. CCUS discussion has been provided in section 6.4.2.5	Qing YANG	Harvard University	China
26315	51	10	51	20	I just note the fact that Tanaka et al. (2019) cited in this paragraph also looked into a wide range of CH4 leakage rates (up to 10%). But as far as the study bases its conclusion on its selected emission metrics, which the study argues are consistent with the time scale of the Paris Agreement targets, the climate benefit of coal-to-gas shift is robust. This paragraph could also touch on other issues like air pollution and induced seismic activities (Jackson et al., 2014, 10.1146/annurev-environ-031113-144051; Weingarten et al., 2015, 10.1126/science.aab1345). I further suggest Raimi (2018, "The fracking debate"), which provides, albeit in a form of non-peer reviewed book, a balanced account on all of these issues, in my view.	Taken into account. These benefits are discussed in 6.7.4 and 6.7.7.	Tanaka Katsumasa	Laboratoire des Sciences du Climat et de l'Environnement (LSCE), CEA, FRANCE; National Institute for Environmental Studies (NIES), JAPAN	France
2155	51	15			I'm not sure the leakage rate of conventional gas systems has been measured globally (or in the US). Citation needed. There is one paper from Pennsylvania showing higher leakage percent rates for conventional than unconventional production wells, but of course unconventional wells produce at much higher rates (Omara et al., 2016; https://pubs.acs.org/doi/abs/10.1021/acs.est.5b05503). After natural gas is produced from conventional and unconventional wells, it goes into the same natural gas supply chain so there is no difference there (maybe the gathering systems are different)	This comment is for 6427 and not 6428. Global estimate are provided for fugitive emissions which include natural gas leakages (section 631 , figure included of fugitive emissions breakdown.). To be cross referenced.	Amy Townsend-Small	University of Cincinnati	United States of America

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
45735	51	19	51	20	Moreover, produced water from such formations is moderately to highly brackish, and treating such waters has large energy and cost implications (Singh and Colosi 2019; Bartholomew and Mauter 2016) . >following literature said “US shale gas wellhead costs have declined since 2012 due to technological progress.The impact of external factors on these costs shouldn't be underestimated.” “Shale gas production costs: Historical developments and outlook” Author: Mélodie Mistré, Morgan Crénes, ManfredHafner (Energy Strategy Reviews Volume 20, April 2018, Pages 20-25 https://www.sciencedirect.com/science/article/pii/S2211467X18300014 Accessed on March 15, 2020) More over, MIT report named ”The Future of Natural Gas”pointed out that “Indeed, the “water intensity” of shale gas development, at around 1 gallon of water consumed for every MMBtu of energy produced, is low compared to many other energy sources. By way of contrast, several thousand gallons of water per MMBtu of energy produced can be used in the irrigation of corn grown for ethanol.” (https://energy.mit.edu/wp-content/uploads/2011/06/MITEI-The-Future-of-Natural-Gas.pdf Accessed on March 15, 2020)”	Taken into account. The water footprint is widely uncertain and we have provided additional literature to justify these statements.	Junko Ogawa	The Institute of Energy Economics, Japan	Japan
15527	51	21	51	29	The discussion of the sociocultural and institutional aspects of fossil energy would seem to be missing how fossil energy actors have engaged in cultural and political processes and ultimately delayed climate action. There is a rich literature on this topic, and I would urge the authors to synthesize it here. See e.g. Brulle, R. J. Institutionalizing delay: Foundation funding and the creation of U.S. climate change counter-movement organizations. Climatic Change 122, 681–694 (2014). Brulle, R. J. The climate lobby: a sectoral analysis of lobbying spending on climate change in the USA, 2000 to 2016. Climatic Change 149, 289–303 (2018). Supran, G. & Oreskes, N. Assessing ExxonMobil’s climate change communications (1977–2014). Environ. Res. Lett. 12, 084019 (2017). Many others	Taken into account. This has been discussed elsewhere	Peter Erickson	Stockholm Environment Institute	United States of America
25073	51	21	51	29	Refer to inefficient fossil fuel subsidies, as some arguments are not aligned with sustainable development issues	Taken into account. This has been discussed elsewhere	Eleni Kaditi	Organization of the Petroleum Exporting Countries (OPEC)	Austria
20759	51	23			"(Merrill et al. 2015; Jakob et al. 2015) Coady et al, 2015)." first ") " should be ";"	editorial. Noted	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	China
9553	51	30			no mention is made of geothermal use for heating purposes	Accepted. In the placeholder, this is highlited and particularly the case of Iceland. Same as comment 609	Tom Kram	PBL (Fellow)	Netherlands
39287	51	31	51	31	Is geophysical really the good term ? The paragraph talks more about georessources than geophysics.	Noted. This word may disappear. The purpose is much more georessources. The content ,is therefore appropriate.It was a guidance for the authors.	Bruno Gavazzi	UMR7516 Institut de Physique du Globe de Strasbourg (CNRS/Université de Strasbourg	France
43325	51	31	52	5	Large potentials are mentioned for geothermal sources world wide. It is however not discussed for how long time the qouted productions figures can last. Are the numbers representing a sustainable energy source on a time scale of centuries of less?	Noted. A couple of lines will be added on life expectancy if relevant.	Aksel Walløe Walloe Hansen	Niels Bohr Intsitute, Uni. of Copenhagen	Denmark
8895	51	37	51	37	Figures on this line seems inconsistent. May be, the potential energy down to 10 km is 1.1 ZetaJ/yr? And the coma in 1,109 should be deleted?	Noted. Figures will be checked and other sources considered	Michel SIMON	Vice Président SFENRAL	France
4465	52	1	52	4	The text could be extended with literature about technological advances in deep geothermal energy, including geothermal cooling.	Accepted. In the box technology development is addressed. This point will be taken into consideration	Leonardo Barreto	Austrian Energy Agency	Austria
31445	52	1	52	5	Here the unequal distribution of geothermal energy is very important to mention (IRENA, 2018)	Accepted. This is addressed in the box (placeholder) but could be placed as suggested and space permitting extented.	Patrick Jochem	German Aerospace Center (DLR)	Germany
43327	52	1	52	5	It could be discussed how relative large geothermal plants may be integrated into large cities in the form of district heating facilities.	Rejected. Beyond scope of this section	Aksel Walløe Walloe Hansen	Niels Bohr Intsitute, Uni. of Copenhagen	Denmark
43329	52	1	52	21	geothermal plants may be used as a storage of wind energy. A combination of solar, wind and geothermal energy installations therefore seem very appropriate. Combined with large heat pumps.	Rejected. Beyond scope of this section	Aksel Walløe Walloe Hansen	Niels Bohr Intsitute, Uni. of Copenhagen	Denmark
31823	52	6	52	7	Is it well established that geothermal energy is renewable and sustainable? That is, like fossil fuels, it will not lead to some unforeseen problem about a 100 years later because it affects earth's geology in some fundamental way - particularly if implemented on a large scale?	Accepted. More information and reference will be provided	Ashok Sreenivas	Prayas (Energy Group)	India
31447	52	6	52	10	I’m not 100% sure whether this is right (there are also dry rock applications using water to my knowledge! Please update and give references!	Accepted. More information and reference will be provided. Same as comment 607	Patrick Jochem	German Aerospace Center (DLR)	Germany

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
8897	52	11	52	14	This paragraph refers only to electricity production. This should be specified. In addition, it's worth to mention that geothermal energy is also use for heating. In Iceland, 90% of the houses and offices are heated by direct geothermy.	Accepted. In the placeholder, this is highlighted and particularly the case of Iceland	Michel SIMON	Vice Président SFENRAL	France
28885	52	24	52	26	Like before, what is the unit of capacity factor? It is obvious a percentage. I think it is better to make it consistent that he y-axis is for the unit just like the installed cost and cost of electricity	Accepted. Althouhg capacity factor definition is quasi universal. Comment will be provided to this figure	Marissa Malahayati	National Institute for Environmental Studies	Japan
16277	52	29	53	4	In the [Environmental/Ecological and Sociocultural] subsection, consider adding a discussion of the potential for oil/gas companies to turn their technological advantage in drilling to a rapid pathway for energy transition. If oil/gas companies could profit by being the major drilling source for hot dry rock geothermal, in developing wells and reservoirs, the transition away from oil and gas might be more readily charted. Such a transition could occur through governmental subsidy of hot dry rock geothermal or EGS in places where coal power is currently in use.	Accepted. In the box technology development is addressed. This point will be taken into consideration	Daniel Helman	College of Micronesia-FSM	Micronesia, Federated States of
34167	52		52		Quick description of the figure would ease understanding [suggestion ENSEEIHT INP]	Accepted. Brief comment will be added	Antoine BONDUELLE	Climate Action Network France	France
39289	53	3	53	3	Very minor comment, but could a more recent citation be used ? A 1991 paper for estimating the environmental impact while there were a lot of technological changes since might not be the strongest	Accepted. Recent ref will be provided. Table on impact is more recent and impact identified still relevant and valid.	Bruno Gavazzi	UMR7516 Institut de Physique du Globe de Strasbourg (CNRS/Université de Strasbourg	France
37029	53	11	54	4	http//www.oceanpanel.org/climate	Taken into account, will be added when possible within word count	Joyashree Roy	Asian Institute of Technology, Thailand. Jadavpur University, India	Thailand
37031	53	11	54	4	The reference mentioned has many upto date information relevant for the section. Ocean as a solution to climate change: five opportunities for action Report Washington DC, World resources institute. http//www.oceanpanel.org.climate. Also will be useful the reference •Safari, A., Das, N., Langhelle, O., Roy, J., &Assadi, M (2019), Natural gas: A transition fuel for sustainable energy system transformation? Energy Science and Engineering, 07 June 2019, (https://doi.org/10.1002/ese3.380).pp 1-20.	Taken into account, will be added when possible within word count	Joyashree Roy	Asian Institute of Technology, Thailand. Jadavpur University, India	Thailand
34169	53	11	54	19	Text does not use the same methodology as the one used for other energy sources (no Geophysical / Technology/ Economic / Environmental subparts) [suggestion ENSEEIHT INP]	Taken into account, will be added when possible within word count	Antoine BONDUELLE	Climate Action Network France	France
34195	53	11	54	19	Not the same methodology as the one used for other energy sources (no Geophysical / Technology/ Economic / Environmental subparts) [suggestion ENSEEIHT INP]	Taken into account, will be added when possible within word count	Antoine BONDUELLE	Climate Action Network France	France
17153	53	11			Further detail could be given on the status of marine energy and the technological, economic and environmental/societal aspects	Taken into account, will be added when possible within word count	Deborah Greaves	University of Plymouth	United Kingdom (of Great Britain and Northern Ireland)
31825	53	12	53	12	While oceans may be a huge source of untapped energy, it may be good to touch upon the negatives or potential risks to the planet / biodiversity etc. of tapping this source.	accepted - text has been rewritten	Ashok Sreenivas	Prayas (Energy Group)	India
9555	53	15	53	21	Check units: TWh/yr or TW?	editorial	Tom Kram	PBL (Fellow)	Netherlands
8899	53	17	53	17	Energy unit has to be corrected and should read as 1 TWh/yr	editorial	Michel SIMON	Vice Président SFENRAL	France
8901	53	19	53	19	Same remak: Ocean waves can provide up to 2 TWh/yr .	accepted - text has been rewritten	Michel SIMON	Vice Président SFENRAL	France
9557	53	20	53	21	Explain what "direction of energy" is and why it cuts the putential by 50%	accepted - text has been rewritten, comment no longer applies	Tom Kram	PBL (Fellow)	Netherlands
10903	53		53		Does the discussion of geothermal also take into account recent advances in and the characteristics of deep geothermal?	Rejected. We did not include this due to space constraints. However, we will revisit in revising for the final draft	Ian Bailey	University of Plymouth	United Kingdom (of Great Britain and Northern Ireland)
16675	53				Table 6-11: seismic events also occur in drilling operations. High temperature systems imply fracking down to large depths. In a slightly active region, Alsace, projects were consequently given up.	Change to noted.	Jean Louis Bobin	Sorbonne universités Paris	France
4467	54	1	54	4	The text should be extended with literature about technological advances in ocean energy.	Taken into account, will be added when possible within word count	Leonardo Barreto	Austrian Energy Agency	Austria

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
24649	54	5	54	19	This is a poor description of "waste-to-energy" systems. The text does not name, let alone describe, the different technologies, nor does it explain the difference between "thermal" and "biological" WTE systems. The definition given -- "technologies that convert non-recyclable waste into energy" would exclude anaerobic digestion, which processes organic waste that could also be composted. It also excludes most incineration as currently practiced, because incinerators rely on paper, cardboard, and plastics -- almost all of which are recyclable -- to maintain combustion. There is therefore a conflict between the text and the figure. The text asserts multiple times that WTE is "sustainable" but in fact this is not the case when the waste in question is either of fossil fuel origin (such as plastic) or is harvested unsustainably (as is the case with much of the paper products and food waste that constitute municipal solid waste). It is certainly not the case for hazardous waste that is often burned in cement kilns. A proper assessment of the potential of WTE for mitigation needs to specify both the waste stream treated as well as the technology employed. It should also acknowledge thorny issues of toxic emissions, byproducts, and energy displacement.	Thank you for the comments. I have revised the text according to the reviewer's comments	Neil Tangri	GAIA	United States of America
29469	54	5	54	19	This Waste-to-Energy section needs to mention the emissions reduction and negative net emissions potential when paired with CCS. There are examples of projects (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.	The text has been revised based on reviewer's comments	Eve Tamme	Global Carbon Capture and Storage Institute	Belgium
27407	54	5			The section is titled and covers 'Waste to Energy'. This is a generic concept that includes different technologies with very different mitigation potential. The section really needs adding further specification about the different technologies - a proposal is provided below.	Accepted and revised	Mariel Vilella Casaus	Zero Waste Europe	United Kingdom (of Great Britain and Northern Ireland)
27409	54	6	54	7	The definition is not accurate as waste-to-energy technology not only uses 'non-recyclable waste'. For example, Waste to energy includes Anaerobic Digestion, for example, which is made with organic waste which is technically considered 'recyclable waste'. The definition should delete 'non-recycable' and provide further explanation of what technologies are included and the different mitigation potential. A proposal is provided below.	I have revised the definition	Mariel Vilella Casaus	Zero Waste Europe	United Kingdom (of Great Britain and Northern Ireland)
30943	54	6	54	16	Waste-to-energy should be more specific about the potential of anaerobic digestion and the treatment of biowaste and waste food	The text has been revised based on reviewer's comments	Pietro Bartocci	University of Perugia	Italy
4471	54	6	54	19	6.4.2.10 on waste to energy could mention impact on methane emissions and include some recent trends (see e.g. IEA, 2018: Renewables 2018)	I have revised the text based on the revoewer's comments	Leonardo Barreto	Austrian Energy Agency	Austria
27411	54	7	54	8	This is misquoted. The article talks about the specific case of Indonesia and of one particular technology of waste to energy, Anaerobic Digestion - it does not back up a global statement. In detail, the article is about: Because of the rapid growth in population, Indonesia is currently facing two challenges; ensuring the security of both future sustainable energy and waste management. Waste to energy technologies such as AD for the production of clean alternative energy in the form of biogas from animal waste is one of the best ways to circumvent these challenges. This work shows that the utilization of organic waste collected from livestock farms and slaughterhouse could potentially be used for biogas production, which could then be used directly for cooking, lighting, and generating electricity. In addition, the organic byproducts (digestate) obtained from this process could also be used for various agricultural purposes. https://www.sciencedirect.com/science/article/pii/S1364032119301042?via%3Dihub#bib47	The text has been revised based on reviewer's comments	Mariel Vilella Casaus	Zero Waste Europe	United Kingdom (of Great Britain and Northern Ireland)
27413	54	8	54	10	This is misquoted and should be edited as 'Biogas made via the anaerobic digestion of organic waste has shown to provide a source for sustainable energy generation and municipal waste management - this is the case in Iran and other countries'. The article does not talk generally about WTE, this term should not be used without being specific about what technology we are referring to, as it can involve very different technologies. https://www.sciencedirect.com/science/article/pii/S1364032113005613	The text has been revised based on reviewer's comments	Mariel Vilella Casaus	Zero Waste Europe	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
27415	54	11	54	13	The source for this is a market research report. It's not peer-review: https://www.grandviewresearch.com/blog/waste-to-energy-the-new-renewable-source-of-energy. Still, the source does provide for a categorisation of waste to energy: This source does explain different waste-to-energy technologies - this should be included in the report to illustrate the figure 6.24. Kinds of waste-to-energy technologies: thermal and biological are the two major technologies used by WtE plants. Thermal: Pyrolysis, gasification, and incineration constitute thermal technology. Although incineration was the major technology used to dispose waste, it emits excessive CO2 into the air. Pyrolysis is the thermochemical putrefaction of organic materials at high temperatures when there is no oxygen. It is carried out heavily in the chemical industry to produce charcoal, methanol, and activated carbon. Gasification converts fossil fuels into synthetic gas (syngas). Pyrolysis and gasification have not been implemented successfully, and they remain at an experimental level. Fossil fuels are added to the waste mix and used for large-scale electricity production, to increase the calorific value of the waste. Biological: Biological processes decompose solid waste anaerobically to generate energy. Their applications include biofuels, fertilizers, and land. They have been employed in American and European countries with supportive environmental policies.	The text has been revised based on reviewer's comments	Mariel Vilella Casaus	Zero Waste Europe	United Kingdom (of Great Britain and Northern Ireland)
11361	54	13	54	13	" Countries in OECD region……China and India in Asia will benefit less"- Little bit of elaboration may be considered to be incorporated.	This part has been removed from the revised draft	PINAKI SARKAR	CSIR-CENTRAL INSTITUTE OF MINING AND FUEL RESEARCH	India
42685	54	13	54	14	Fig 6.24 need to be redrawn	Fig.6.24 has been removed from the revised draft	ABHA CHHABRA	Space Applications Centre, Indian Space Research Organisation	India
28887	54	13	54	15	What is the unit for this figure?	The figure has been removed from the revised draft	Marissa Malahayati	National Institute for Environmental Studies	Japan
4469	54	16	54	17	Waste-to-energy technologies must be integrated into holistic waste management concepts and, if possible, their use should be embedded in a waste hierarchy, a priority order of what constitutes the best overall environmental option in waste legislation and policy (DIRECTIVE 2008/98/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 19 November 2008 on waste and repealing certain Directives, https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32008L0098&from=EN	The text has been revised based on reviewer's comments	Leonardo Barreto	Austrian Energy Agency	Austria
27417	54	16	54	17	This statement is lacking a credible source. Also, it does not distinguish different WTE technologies, which again is problematic because not all WTE technologies produce sustainable energy. The European Union has recently excluded Waste-to-Energy incineration from the new EU Sustainable Finance Taxonomy Report which includes a list of economic activities considered sustainable; those that can make a substantial contribution to climate change mitigation and which do no significant harm to other environmental objectives such as transition to a Circular Economy, waste prevention and recycling. The section needs to provide a categorisation of different technologies and its specific climate change mitigation potential and contribution to other environmental benefits. European Commission, Technical Expert Group on Sustainable Finance, Technical Report on EU Taxonomy, June 2019. Available here: https://ec.europa.eu/info/publications/sustainable-finance-teg-taxonomy_en	This has been revised	Mariel Vilella Casaus	Zero Waste Europe	United Kingdom (of Great Britain and Northern Ireland)
36515	54	16	54	19	Clarification; What kind of waste is assumed here? Why more CO2 is emitted from waste-incineration? In Japan, many of large scale waste incineration plants for municipal waste are equipped with generation and its biomass contents is around 70% and plastics accounts for around 20% (in case of Tokyo, please see below). No additional fuel is needed for incineration. https://www.union.tokyo23-seisou.lg.jp/gijutsu/kankyo/toke/documents/h30gominonakami_1.pdf Is "more CO2 emission than goal and gas" proper explanation?	Clarifications have been provided now	Takashi Hongo	Mitsui & Co. Global Strategic Studies Institute	Japan
27419	54	17	54	17	Although the incineration process reduces the volume of MSW by up to 90%, 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. This information needs adding to the description of waste to energy incineration.	We have deleted this. This statement is very good but the publication date of the literature is 2008, which is earlier than the at least 2015 published papers that is expected to be cited in this draft	Mariel Vilella Casaus	Zero Waste Europe	United Kingdom (of Great Britain and Northern Ireland)
31827	54	17	54	19	Aren't there concerns about other toxic emissions too from waste combustion?	This has been addressed in the revised text	Ashok Sreenivas	Prayas (Energy Group)	India

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
6039	54	18	54	18	To check the year for publication for Urso Campos et al (2008) as it refers to 'Campos, Urso, Zamenian, Hamed; Koo, Dan Ph.D., Goodman, David W. Waste To Energy Technology Applications for Municipal Solid Waste Treatment in the Urban Environment. International Journal of Emerging Technology and Advanced Engineering. Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 5, Issue 2, February 2015).'	This has been corrected in the revised text	SAIK PENG, CASEY NGO	R-SYNC TECHNICAL RESOURCES SDN. BHD.	Malaysia
27421	54	18	54	18	This is misspelled. It's Urso Campos et al	This reference is no more cited in the revised text	Mariel Vilella Casaus	Zero Waste Europe	United Kingdom (of Great Britain and Northern Ireland)
6041	54	18	54	19	The clause '... can generate more carbon dioxide emission, than coal, natural gas or oil.' originates from another literature quoted within Urso Campos (2015) i.e. [4] Mulvaney, D. and Robins, P. (2011). “Green technology.” Washington, D.C., Sage. Platt, P., Ciplet, D., Balley, K. M., and Lombardi, E. (2008). “Stop trashing the climate.” Washington, D.C., Institute for Local Self-Reliance, Global Anti-Incinerator Alliance/Global Alliance for Incinerator Alternatives, Eco-Cycle. http://www.stoptrashingtheclimate.com/fullreport_stoptrashingthecli mate.pdf '	This has been corrected in the revised text	SAIK PENG, CASEY NGO	R-SYNC TECHNICAL RESOURCES SDN. BHD.	Malaysia
18023	54	19	54	19	Unless fitted with CCS, eg Pour (2018) Int Journal Greenhouse Gas Control Vol68, p1	I have revised the text based on the revoewer's comments	Tim Dixon	IEAGHG	United Kingdom (of Great Britain and Northern Ireland)
41995	54	19			At the end of the sentence, include "depending on the energy mix associated to the given geographical area"	The sentence has been revised.	Francisco Javier Hurtado Albir	European Patent Office	Germany
13855	54	20	54	20	Might worth mentioning energy storage using solid materials and gravity, somewhere this part. Even if techno-economic feasibility is questionable, public might want the IPCC mentioning it as there is a non-zero mediatic exposure . Example : https://www.energytoday.net/energy-conversion-storage/gravity-the-solution-to-energy-storage/.	Inserted into pumped storage section	Alexandre Bizeul	International Energy Agency	France
31275	54	20	58	9	Include one additional subsection on PtX storage. PtG (e.g. methane) and PtL (e.g. methanol, efuels) can provide important services in the energy system and will be needed (e.g. for transportation, for industry, as feed stock, and in those regions w/o sufficient potential for RE production, also for power generation). Further more, energy imports will be needed in many regions. Currently, you show only hydrogen as a chemical fuel / chemical storage. But clearly, also drop-in fuels (e.g. methane, efuels) will be needed in many energy systems and/or many applications (e.g. for transport applications and for applications in buildings).	accepted	Urs Ruth	Robert Bosch GmbH	Germany
4473	54	20	58	10	Section 6.4.3. refers mostly to electricity storage. Heat storage technologies are not discussed. They should be included.	Rejected. TES is included	Leonardo Barreto	Austrian Energy Agency	Austria
31449	54	20	59	1	In Chapter 6.4.3 I’m missing the P2X approach! Only hydrogen is mentioned. To my understanding, P2X is a core technology in many IAM/Energy system models if carbon neutral scenarios are considered.	duplicate - same as 31275	Patrick Jochem	German Aerospace Center (DLR)	Germany
38033	54	20	59	1	I suggest to add text or table showing how much capacity is installed worldwide of different storage technologies. It is important to show that today the different technologies are at very different deployment scales. Pumped storage reperesents 95 % of all grid-connected storage whereas some technologies are either almost not deployed (CAES) or in a very early stage (Liquid air energy storage, supercapacitors)	reject: insufficient space for a table; installed capacity mentioned in some technologies	Atle Harby	SINTEF Energy Research	Norway
34171	54	21	59		Lacks the actual numbers of the different energy features (Energy capacity,density , efficiency) for each energy storage technology. [suggestion ENSEEIHT INP]	Table 6.63 to be removed altogether	Antoine BONDUELLE	Climate Action Network France	France
31451	54	26	54	27	You may replace “support the electrification of transport and heat” by “decrease curtailment”.	text has changed since - original sentence no longer present	Patrick Jochem	German Aerospace Center (DLR)	Germany
18703	54	34	54	34	Table 6.512 and key features compared in Table 6.613 - an error in the digits after the table numbers	text has changed since - original sentence no longer present	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
24341	54	36	55	2	The last sentence is very optimistic. We have no idea if we can achieve it.	reject - text specifies significant opportunitires	Alan BURLOT	Commissariat à l'énergie atomique et aux énergies alternatives	France
25075	54		54		Include unit in Figure 6.24	This is related to section 6.4.2 and it is out of scope of our work	Eleni Kaditi	Organization of the Petroleum Exporting Countries (OPEC)	Austria
20761	54				What is the Unit of the Y axis in Figure6.24	Unit added	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	China

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
23937	55	3	55	3	The provision of intermediates from biomass is also a storage option, including a wide range of supply options for the energy system (see i.e. http://task44.ieabioenergy.com/, but also: Thrän, D., Dotzauer, M., Lenz, V., Liebetrau, J., Ortwein, A., (2015): Flexible bioenergy supply for balancing fluctuating renewables in the heat and power sector—a review of technologies and concepts. Energy Sustain. Soc. 5 , art. 35.	Rejected - Limited space; biomass is not power-to-power or power-to-heat and is rarely included in ES reviews	Stefan Majer	German Biomass Research Centre - DBFZ	Germany
38031	55	3	55	15	Please add developments in using seawater pumped storage to the paragraph on pumped storage.	accepted	Atle Harby	SINTEF Energy Research	Norway
16281	55	3			For Section 6.4.3.1 Pumped hydro energy storage (PHES), consider adding a description of underground pumped hydro, as an aid to the reader, and for clarity and accuracy.	accepted	Daniel Helman	College of Micronesia-FSM	Micronesia, Federated States of
41997	55	3			6.4.3.1. PHES presents the same problems as hydropower, and this should be mentioned	reject, comment does not clarify the problems	Francisco Javier Hurtado Albir	European Patent Office	Germany
6375	55	4	55	5	It is suggested to use ‘where the kinetic energy of the falling water drives turbines to produce electricity’	accepted	Sciacovelli Adriano	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
6455	55	4			PHES uses cheaper electricity to pump water. This is not necessarily excess electricity.	accepted	Paul Neetzow	Humboldt-Universität zu Berlin	Germany
18705	55	6	55	6	PHES is a well-established technology' - Barbour et al. paper that is already in the reference list - but currently used incorrectly (as it is not suitable for an ammonia reference) - could be used here as a reference for the statement 'PHES is a well-established technology'	accepted	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
6381	55	6	55	9	The Sentences about i) LAES being and hybrid latent TES and CAES and ii) PTES being a hybrid sensible TES and CAES should be revised to be more technically accurate. In LAES there is not such storage of thermal energy using latent heat but rather a liquefaction process of air (during charge) and an evaporation process of air (during discharge). The statement ‘LAES being and hybrid latent TES and CAES’ would be equivalent to say that a refrigeration system (which also have condensation and evaporation) is also an hybrid of latent TES and compression (which is not the case)	accepted	Sciacovelli Adriano	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
37991	55	8	55	9	There are very few pumped storage plants that can deliver power for more than some hours. I suggest to rephrase to: "Pumped hydro is best suited for longer periods of energy storage of multiple hours, and in special cases even for days."	accepted	Atle Harby	SINTEF Energy Research	Norway
27941	55	10	55	10	IPCC states, "TES is best suited to energy storage periods in the multiple hours to days range." Please correct this statement, since three types of themal energy storage: Borehole storage, water pit storage, and aquifer storage, are designed to store heat or cold seasonally as well as daily and are commercially available worldwide and have been for about two decades.	accepted, same as 2347 & 12643	Mark Jacobson	Stanford University	United States of America
20385	55	16	55	32	CAES has an excellent geological storage potential which underpinns the prospects: https://www.sciencedirect.com/science/article/pii/S0196890418305351	accepted	Christian Breyer	LUT University	Finland
6377	55	20	55	21	Does ‘No fuel CAES’ actually refers to Adiabatic CAES? Please clarify since ‘no fuel CAES’ is not commonly used in the literature.	accepted	Sciacovelli Adriano	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
31829	55	22	55	22	Should be "however, it is still NOT considered" …	Rejected; it is considered to be commercial, rather than mature. Perhaps definitions of these commercial readiness terms need to be included in the caption for table 6.63?	Ashok Sreenivas	Prayas (Energy Group)	India
6379	55	25	55	28	‘Heat losses’ commonly refers to dissipation of heat toward the environment. Here however it the context of CAES efficiency can be improved by proper management of the heat streams during compression and expansion of air. Please revise the sentence.	accepted	Sciacovelli Adriano	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
1531	56	0	56	0	#REF!	All reference are inlcuded	Paul Vethman	PBL Netherlands Environmental Assessment Agency	Netherlands
2343	56	3	56	3	")" missing	accepted	Dieter Boer	Universitat Rovira i Virgili	Spain

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
2345	56	5	56	5	update references for thermochemical TES: Ruby-Jean Clark, Abbas Mehrabadi, Mohammed Farid, State of the art on salt hydrate thermochemical energy storage systems for use in building applications, Journal of Energy Storage, Volume 27, 2020, https://doi.org/10.1016/j.est.2019.101145. Cristina Prieto, Patrick Cooper, A. Inés Fernández, Luisa F. Cabeza, Review of technology: Thermochemical energy storage for concentrated solar power plants, Renewable and Sustainable Energy Reviews, Volume 60, 2016, Pages 909-929, https://doi.org/10.1016/j.rser.2015.12.364.	accepted	Dieter Boer	Universitat Rovira i Virgili	Spain
2347	56	10	56	11	Inlcude at the end of the paragraph comment on seasonal storage: But also seasonal storage application are advancing and several installation soalr assisted installations are working with very high solar fractions. Reference: Abdulrahman Dahash, Fabian Ochs, Michele Bianchi Janetti, Wolfgang Streicher, Advances in seasonal thermal energy storage for solar district heating applications: A critical review on large-scale hot-water tank and pit thermal energy storage systems, Applied Energy, Volume 239, 2019, Pages 296-315, https://doi.org/10.1016/j.apenergy.2019.01.189.	accepted, same as 27941 & 12643	Dieter Boer	Universitat Rovira i Virgili	Spain
12643	56	10	56	11	"TES is best suited to energy storage periods in the multiple hours to days range, depending on the technology." This comment does not take recent development in terms of large scale pit storages used for seasonal storage into account. This is implemented in Denmark in particular for storage of solar heating in district heating networks. See e.g. https://doi.org/10.1016/j.enconman.2019.03.071	accepted, same as 2347 & 27941	Marie Münster	Technical University of Denmark	Denmark
31453	56	45	56	47	You may give a reference here for this negative picture of the LIB. To my knowledge the LIB life-time exceeds usually 20 years – or it at least longer lasting than electric vehicles (if the battery management is well organized). Also the “ignite a fire” is true, but not a real problem in my eyes (compared to gasoline, diesel, gas, etc.). The same is true for the resource availability where I have seen studies which are very optimistic when it comes to more than 1 billion electric cars.	references updated; lifetime here should be viewed in the context of grid-scale storage, not EVs and battery degradation is still an active area of research. Safety factors in newer technologies always need to be more stringently controlled than for incumbents, because public perception of safety is just as important as actual risks. There are still elements in LIBs which are limited and resource availability is an issue for the long-term (beyond the next 5 years) future of LIBs, if recycling is not deployed.	Patrick Jochem	German Aerospace Center (DLR)	Germany
4475	56	47	57	2	The problems with disposal of used batteries must also be adressed	accepted	Leonardo Barreto	Austrian Energy Agency	Austria
31455	57	2	57	2	I would change the “the 0.5 to 4 hour range” to “up to one cycle a day” (which is the usual application in German households, where LIB are applied successfully). If required I may provide some references.	accepted	Patrick Jochem	German Aerospace Center (DLR)	Germany
31457	57	3	57	11	This is rather old literature we may update it!	accepted	Patrick Jochem	German Aerospace Center (DLR)	Germany
42003	57	3			An efficient operation of batteries, compatible with modern challenges of its use (mobility, portability, fast and efficient charging …) would not be possible without power electronics, instrumental for battery charging and operation. Although power electronics is already at commercial loevel, research needs for mpore efficent power converters and technologies (power semiconductors, magnetric materials, panar coils, integration ..) is necessary, in particular aftter the growing extension of wireless charging in electromobility or portable devices.	Reject – not directly relevant	Francisco Javier Hurtado Albir	European Patent Office	Germany
42005	57	13			"Supercapacitors; ULTRACAPACITORS OR DOUBLE-LAYER CAPACITORS"	accepted	Francisco Javier Hurtado Albir	European Patent Office	Germany
42007	57	19			At the end of the paragrapoh it shiuld be explained that supercapcitors offer a very interesting synergie with batteries when combined. Supercapacitors offer a very interesting energy density and also the abiulity to supply high peaks of power.	accepted	Francisco Javier Hurtado Albir	European Patent Office	Germany
30951	57	25	57	37	in this paragraph there is no hint at electrolysers which are one of the most promising way to produce H2.- Also powert to gas should be hinted at	reject: electrolysis is explicitly stated!	Pietro Bartocci	University of Perugia	Italy

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
42961	57	25	57	37	I think that paragraph 6.4.3.8 “Hydrogen and Reversible Hydrogen Fuel Cells (H/RHFC)” need to be revised and updated for SOD-Draft. I suggest to read and include consideration and data analyzed in: the US DOE document “Hydrogen Production Cost From PEM Electrolysis – 2019” [February 3, 2020; available at <https://www.hydrogen.energy.gov/pdfs/19009_h2_production_cost_pem_electrolysis_2019.pdf>]; and the report prepared by the IEA for the G20, Japan: “The Future of Hydrogen Seizing today’s opportunities” [June 2019; “Chapter 2: Producing hydrogen and hydrogen-based products” (“Hydrogen from water and electricity”), p.42; available at <https://www.iea.org/hydrogen2019/> and <https://webstore.iea.org/download/direct/2803>].	accepted, but please note: some of these refs weren't even published at the time of writing and are not widely available	MARIO VALENTINO ROMERI	Independent consultant	Italy
31459	57	26	57	37	This section is very short compared to its potentials (cf. Section 6.4.4.1 and Box in Section 6.6 on the Hydrogen Society)! I would definitely enlarge this section!	Reject; It is the same size as others within the section on ES; hydrogen is dealt with in other sections; box 6.17 is "The Hydrogen Economy"; add PtX and refer to hydrogen transport	Patrick Jochem	German Aerospace Center (DLR)	Germany
34693	57	29	57	30	Suggested reference: Paolo Gabrielli, Alessandro Poluzzi, Gert Jan Kramer, Christopher Spiers, Marco Mazzotti, Matteo Gazzani,Seasonal energy storage for zero-emissions multi-energy systems via underground hydrogen storage,Renewable and Sustainable Energy Reviews,Volume 121,2020,109629,ISSN 1364-0321,https://doi.org/10.1016/j.rser.2019.109629.	accepted	Jordi Solé-Ollé	Spanish National Research Council (CSIC)	Spain
30947	57	34	57	37	water splitting and artificial photosynthesis can be named also as research needs	Reject – not directly relevant	Pietro Bartocci	University of Perugia	Italy
20387	57	45	57	46	latest insights on battery cost and further projections here: https://onlinelibrary.wiley.com/doi/full/10.1002/pip.3189	accepted	Christian Breyer	LUT University	Finland
6383	58	9	58	9	Table 6.52. It should be clarified why CAES can provide Fast Reserve but LAES not CAES and LAES largely share the same type of equipment (compressor, turbine, heat exchangers, etc) and thus largely the same dynamic behavior/response time/ramp rates. Also references (number in bracket) cannot be found in the Bibliography of the Chapter, which uses a different referencing style	accepted	Sciacovelli Adriano	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
28889	58	9	58	9	What is the meaning of value inside the brackets on colomn top-bar?	duplicate - same as comment 30949	Marissa Malahayati	National Institute for Environmental Studies	Japan
28891	58	9	58	9	I suggest you remind the reader about the acronym of PHES, CAES, etc for this table. Kindly write it on the notes.	accepted	Marissa Malahayati	National Institute for Environmental Studies	Japan
38007	58	9	58	9	Is PHES / Conventional Storage Hydro properly represented in the table, it may need review ?	accepted	Atle Harby	SINTEF Energy Research	Norway
8823	58	9	58	10	It would be good to highlight which of these battery services help grid integration of wind/solar (table 6.52).	rejected - not enough space to do this properly for a variety of technologies	Saygın Değer	SHURA Energy Transition Center	Turkey
37995	58	9	58	10	Pumped hydro cannot provide seasonal storage, However, storage hydropower can provide this, both storage hydropower equipped with a pump or conventional storage hydropower where the sun driving the hydrological cycle is the "pump"	accepted	Atle Harby	SINTEF Energy Research	Norway
31277	58	9			Include one (PtX) or two (PtG and PtL) additional column(s) in the table. PtG (e.g. methane) and PtL (e.g. methanol, efuels) can provide important services in the energy system and will be needed (e.g. for transportation, for industry, as feed stock, and in some regions also for power generation). Further more, energy imports will be needed in many regions. Currently, you show only hydrogen as a chemical fuel / chemical storage. But clearly, also drop-in fuels (e.g. mehtane, efuels) will be needed in many energy systems and/or many applications.	reject; insufficient space	Urs Ruth	Robert Bosch GmbH	Germany
31461	58	10	58	10	Why is RHFC not suitable for fast reserve?	accept	Patrick Jochem	German Aerospace Center (DLR)	Germany
20765	58		59		what is the meanning of the number below the name of the storge technologies, like "[42,43]" in the table6.52, table 6.63	duplicate - same as comment 30949	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	China
20763	58				wrong of the number of table6.52. table 6.63	seems to be a formatting issue	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	China
30949	59	1	59	1	table 6.63 the first row contains all citations which are not reported in bibliography	seems to be a formatting issue	Pietro Bartocci	University of Perugia	Italy
31463	59	1	59	1	Why is the efficiency for RHFC Low and not Medium? Why is the environmental impact from LIB uncertain (I have seen so many LCA analyses on this topic)? Why should LIB’s Maturity only demonstration? I have seen many LIB in the electricity system in Africa, Asia and Europe.	Table 6.63 to be removed altogether	Patrick Jochem	German Aerospace Center (DLR)	Germany

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
37993	59	1	59	20	I don't agree with the qualitative evaluation of technologies of energy storage, and I find it very strange that the technology applied for >95 % of all storage, do not have better score. I think it is a reason why almost all grid-connecte storage have been pumped hydro. For instance, I find it very strange that the authors claim the energy density in air is higher than in water? Also, pumped storage has an overall efficiency of about 80 % while CAES has around 30 % when including the gas turbine that actually generates the electricity. I suggest that the whole table is revised and then every evaluation must be documented and referenced	Table 6.63 to be removed altogether; same as 34171	Atle Harby	SINTEF Energy Research	Norway
5897	59	1			This whole section on energy transport has no reference to Chapters 8, 9 10. Were any discussions held between author teams to eliminate duplication and avoid possible inconsistencies between the texts.. Cannot find any discussion of blockchain, AI, and decentralised energy systems. eg see https://unfccc.int/documents/200379	All reference are inlcuded	Ralph Sims	Massey University	New Zealand
6385	59				Table 6.63. Energy cost of CAES appears underestimated; Please revise	Table 6.63 to be removed altogether	Sciacovelli Adriano	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
20389	59				Table 6.63 requires an update on LIB cost, see here: https://onlinelibrary.wiley.com/doi/full/10.1002/pip.3189	Table 6.63 to be removed altogether; duplicate - same as 20387	Christian Breyer	LUT University	Finland
39181	60	1	60	1	This section has an odd selection of technologies. Most energy today is transported as fossil fuel, e.g. natural gas, crude oil or coal, which is not mentioned. Electricity transmission should come before H2, since it is more widespread. What about methanol?	Regarding the first point, we tried to investigate the future technologies that can play a major role in the energy transport, where decarbonisation targets should be achieved. Hence the already well known carriers are not mentioned. As you mentioned methanol is a useful product of hydrogen, which is used widely for industrial applications. However, since the focus here is more on energy transport, due to greenhouse gas emission that methanol produces, this option is not considered. We added a section on Power-to-X where methanol is mentioned.	Tom Brown	Karlsruhe Institute of Technology	Germany
17709	60	1	63	24	Referring back to my comment about the impact of LNG prices and the potential for LNG to displace a sizeable fraction of new coal build - and also, given the challenges in decarbonising heat, and concerning interseasonal energy storage. I suggest the authors seriously consider elevating the prominence and framing of this section, for example, titled something like "Gas, heat and infrastructure - challenges and options for decarbonising molecules and providing interseasonal storage". If so, a really big question strikes me as the relationship between pipes and LNG. Clearly, well-managed pipes are lower carbon (and potentially lower methane) than LNG, but LNG may provide more long term options for decarbonising since it already involves stages of industrial processing. Unfortunately I know of very little literature around this - almost the only study opening this question is Jonathan Stern (2019) Narratives for Natural Gas in Decarbonising European Energy Markets, Oxford INstitute for ENergy Studies, https://www.oxfordenergy.org/wpcms/wp-content/uploads/2019/02/Narratives-for-Natural-Gas-in-a-Decarbonisinf-European-Energy-Market-NG141.pdf	This comment seems not that relevant, since it is mentioned "referring back ...", where we did not have any other comments from this reviewer. Anyways, In this section we tried to provide insights on energy transport through hydrogen/ammonia mainly. In the transmission infrastructure, we have two type of pipelines which one of them is gas pipelines where the gas will be extracted and injected from the terminals to the network. and second are the LNG pieplines where transport the imported gas from other countries to the network.	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
31279	60	1			Include subsections on PtG and PtL for energy transport. PtG/methane will be important as a drop-in fuels to replace fossil natural gas. It can make use of existing transmission infrastructure as well as end-use infrastructure. PtL (e.g. methanol or efuels) will be needed in the transportation sector, because electrification and biofuels are not sufficient. In many contries PtG and PtL will need to come from imports. Therefore it is necessary and very important to discuss PtG and PtL fuels in section 6.4.4 (Energy Transport ...). The lead-time for the industrialization of PtX is very long - especially given that there is no positive business case today; therefore it is very important to highlight the future need for PtX to support its timely industrialization. Otherwise, the climate targets cannot be reached.	The required text and references are added and Table 6.76 on synthetic fuels is provided. Besides , in order to achieve low/zero carbon targets, a statement on continuing use of natural gas or synthetic fuels (carbon-based) through introducing negative emission technologies such as biomass with CCS and direct air capture is presented. : "Hydrogen could be used with captured CO2 to produce synthetic fuels (Power-to-X) such as ammonia, methanol, synthetic methane, and synthetic oil products (IRENA 2019). Such alternative fuels are drop-in solutions to move away from fossil fuel as: (a) it can be used in existing infrastructure in the intensive industries and in the transport sector (Gumber and Gurumoorthy 2018; Schemme et al. 2017; Transport & Environment 2018; DENA 2017), (b) can benefit from the liquefied natural gas (LNG) industry, and (c) easier storage for hydrogen (IRENA 2019). In the transport sector, synthetic methane 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 CO2 based fuels (Gumber and Gurumoorthy 2018). On the downside, if the CO2 is captured from fossil fuel combustion process, there are still CO2 emissions and this is not in line with the Paris climate objectives. Hence, to abate the greenhouse gas emissions, the CO2 should be captured from biomass or from direct air capture (DAC) technologies (IRENA 2019). DAC is a costly technology; however, the projection is to reach below 60 USD/tCO2 in 2040 (Fasihi et al. 2019). "	Urs Ruth	Robert Bosch GmbH	Germany
39187	60	7	60	7	Other useful reviews of the role of hydrogen in the economy are e.g. https://doi.org/10.1039/C8EE01157E and http://dx.doi.org/10.1016/j.ijhydene.2014.11.059.	The mentioned references are added: 1. "For natural gas reforming, the CCS will add on average 50% on the CAPEX and 10% for fuel as well as 100% of OPEX, while for coal gasification, the CAPEX and fuel cost is expected to increase 5% and OPEX by 130% (IEA 2019; Staffel et al 2019)." 2. "Hydrogen can be produced from fossil fuels, biological material and water (Dodds et al 2015)."	Tom Brown	Karlsruhe Institute of Technology	Germany
10139	60	7	60	34	Chapter 6.4.4.1 Hydrogen: Low carbon Energy Fuel. This paragraph is really outdated information. In the previous point already the development in fuel cell and electrolyser investment cost are mentioned. But in table 6.74 electrolysis is mentioned with an efficiency of 92% and in the text there is only mentioned Solid Oxide Electrolysis cells. But this is an electrolysis cell that is under development and that potentially can achieve 92% efficiency on HHV. Present day mature electrolysis technology for water splitting are alkaline electrolysers and mature but not have reached low enough cost is PEM electrolysis. In the table also cost estimates for hydrogen is presented, but that depends of course a lot on the assumed Capex cost and even more on the energy cost. For all these technologies the hydrogen cost are for 60-80% determined by the energy cost. So energy cost are the dominant factor, for electrolysis it is the electricity cost. With an efficiency of 80% on HHV, every 10 dollar/MWh electricity cost translates in 0.5 dollar/kg of Hydrogen. In the IEA report the future of Hydrogen https://www.iea.org/reports/the-future-of-hydrogen a sensitivity analysis for load factor, capex and energy cost can be found. And in the table below in a recent to be published report 'Green Hydrogen for a European Green Deal , a 2x40 GW initiative for 2030 that will be published in March 2020 on the site of Hydrogen Europe the following table is included Hydrogen production by electrolysers* Capex €/kW) OPEX (%/yr Capex) System Efficiency (HHV) Electricity (€/MWh) Hydrogen cost (€/kg) 2020-2025300-6001.5%75-80%25-501.5-3.0 2025-2030250-5001%80-82%15-301.0-2.0 Up to 2050<200<1%>82%10-300.7-1.5 the cost figure for electrolysis of 90 pound/MWh which is 3.5 pound per kilo, is clealy too high.	A separate table on electrolysis and different technologies is provided (Table 6.75) and the relevant text is added. Unfortunately we did not find the reference of Green Hydrogen for a European Green Deal, and we provided the data from IEA report the future of Hydrogen on the CAPEX. As mentioned, the production cost is highly dependent on region and cost of renewables. This is the added text: "Three main electrolysis technologies are; alkaline electrolysis, proton exchange membrane (PEM) electrolysis, and solid oxide electrolysis cells (SOECs), where the estimated CAPEX and efficiencies are provided in Table 6.75 (IEA 2019; Fasihi and Breyer 2020). According to (IEA 2019), the production cost of hydrogen through electrolysis process is dependent to the electricity price and operating hours."	Ad van Wijk	Technical University Delft	Netherlands
19867	60	7	63	24	Three subsections 6.4.4.1 Hydrogen: Low-Carbon Energy Fuel, 6.4.4.2Ammonia: Promising Hydrogen Energy Carrier and 6.4.4.3 Challenges around hydrogen energy fuels should be one subsection under 6.4.4 Energy Transport and Transmission.	we believe the current format looks more comprehensive. However the subsection 6.4.4.2 is siginifcantly enhanced and the title has been changed.	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
41999	60	7			6.4.4.1. This chapter shouls refer to "HYDROGEN ROADMAP EUROPE. A SUSTAINABLE PATHWAY FOR THE EUROPEAN ENERGY TRANSITION" (https://www.fch.europa.eu/sites/default/files/Hydrogen%20Roadmap%20Europe_Report.pdf) prepared for the Fuel Cells and Hydrogen 2 Joint Undertaking. The report represents the view of the industry represented by Hydrogen Europe. It was developed with input from 17 companies and organizations: Air Liquide S.A., BMW Group, Deutscher Wasserstoff- und Brennstoffzellenverband, Enagás, Engie, Equinor ASA, N.V. Nederlandse Gasunie, Hydrogenics, ITM Power, Michelin, NEL Hydrogen, Plastic Omnium, Salzgitter AG, Solid Power, Total SA, Toyota Motor Europe, and Verbund. This report makes the case that achieving the energy transition in the EU will require hydrogen at large scale.	The following text and the reference is added: "To achieve the energy transition, hydrogen at large scale is required, since it offers a versatile, clean, and flexible energy vector for a decarbonised future (Fuel Cells and Hydrogen Joint Undertaking 2019). "	Francisco Javier Hurtado Albir	European Patent Office	Germany
39183	60	8	60	16	Other uses of hydrogen are as a feedstock for the chemical industry (for ammonia or ethylene) or for direct reduction of iron ore, see https://doi.org/10.1016/J.JCLEPRO.2018.08.279 for power-to-steel.	The relevant reference is added in text: "(e.g., as feedstock for the chemical industry or direct reduction of iron ore (Vogl et al. 2018))"	Tom Brown	Karlsruhe Institute of Technology	Germany
42001	60	10			"One signiicant potential fr hydrogen to contribute DEPENDING ON THE ORIGIN OF HYDROGEN"	That is correct and this phrase is added to the text:"Hydrogen production costs has regional variations and it is dependent on many factors such as price of fossil fuels, electricity, and carbon (IEA 2019). "	Francisco Javier Hurtado Albir	European Patent Office	Germany
18707	60	15	60	16	potentially enabling significant reduction in emissions in electricity system' - this sentence may benefit from a further qualification - 'potentially enabling significant reduction in emissions of the electricity system, particularly in terms of low-carbon dispatachable generation to balance available weather dependent renewable generation and demand.'	The text has been amended accordingly	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
34393	60	16	60	16	Please add: hydrogen, when produced via water electrolysis using RE, could be used with captured CO2 to produce synthetic fuels, such as e-methane, methanol, etc…Such alternative fuels are drop-in solutions to move away from fossil fuel as it can be used in exisiting infratstructure in the intensive industries and in the transport sector.(Gumber and Gurumoorthy, 2018, Methanol, Chap. 25, 661-675/ Schemme et al., 2017, Fuel, 205, 198-221./ Muratori et al., 2018, Energies 2018, 11, 1171/ Transport and Environment, 2018: How to decarbonize European transport by 2050, Transport and Environment./DENA, 2017, The potential of electricity-based fuels for low-emission transport in the EU: An expertise by LBST and dena (German Energy Agency).)	The relevant text and references are added. Besides , in order to achieve low/zero carbon targets, a statement on continuing use of natural gas or synthetic fuels (carbon-based) through introducing negative emission technologies such as biomass with CCS and direct air capture is presented. Furthermore Table 6.76 is added to provide production costs of e-fuels: "Hydrogen could be used with captured CO2 to produce synthetic fuels (Power-to-X) such as ammonia, methanol, synthetic methane, and synthetic oil products (IRENA 2019). Such alternative fuels are drop-in solutions to move away from fossil fuel as: (a) it can be used in existing infrastructure in the intensive industries and in the transport sector (Gumber and Gurumoorthy 2018; Schemme et al. 2017; Transport & Environment 2018; DENA 2017), (b) can benefit from the liquefied natural gas (LNG) industry, and (c) easier storage for hydrogen (IRENA 2019). In the transport sector, synthetic methane 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 CO2 based fuels (Gumber and Gurumoorthy 2018). On the downside, if the CO2 is captured from fossil fuel combustion process, there are still CO2 emissions and this is not in line with the Paris climate objectives. Hence, to abate the greenhouse gas emissions, the CO2 should be captured from biomass or from direct air capture (DAC) technologies (IRENA 2019). DAC is a costly technology; however, the projection is to reach below 60 USD/tCO2 in 2040 (Fasihi et al. 2019). "	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
39291	60	17	60	21	Not truly a production method, but there is also the native hydrogen ressources that could be mentionned here (I do not now precisely the formation process, I work on the characterization of reservoirs). Even if it is not in production phase	Thanks for this. We tried to find some proper references on this issue. Unfortunately, we did not find any proper references on the native natural resources of hydrogen (it was only a website https://eosys.fr/resources/natural-hydrogen/)	Bruno Gavazzi	UMR7516 Institut de Physique du Globe de Strasbourg (CNRS/Université de Strasbourg	France
39683	60	17	60	21	a and b are presented without CCS here, while with CCS. In table 6.74, all of them are described with CCS. The CCS part is in itself not a part of the process, and could very well be used for all three, but be clear about this, and separate the costs for the processes and CCS, respectively. Also, explain which process dominates today, with or without CCS.	The table has been updated and all with CCS are provided to have low carbon foot print. Also the following text is added: "For natural gas reforming, the CCS will add on average 50% on the CAPEX and 10% for fuel as well as 100% of OPEX, while for coal gasification, the CAPEX and fuel cost is expected to increase 5% and OPEX by 130% (IEA 2019; Staffel et al 2019). "This actually indicates how the costs would be without CCS. Currently, the CCS technology is not been used widely due to the associated costs. However for a decarbonised future it should be a key factor.	Simon Davidsson Kurland	Chalmers University of Technology	Sweden

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
12383	60	17	60	23	Please consider to rephrase this sentence to the following: "Hydrogen with low carbon footprint can be……..(a) steam methane reforming (SMR) with carbon capture and storage (CCS)….(b) autothermal reforming (ATR) with CCS…. and (c) biomass gasification with CCS……"	The text has been amended accordingly	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
39139	60	17	60	34	nuclear energy can be introduced as one of hydrogen production technologies	Nuclear is added to the text: "and (d) from low/zero carbon energy sources such as renewables and nuclear (e.g., High Temperature Reactors (HTR) (Jaszczur et al. 2016)) " and "low/zero carbon generation technologies such as Renewable Energy Resources (RES) (Kraemer 2018) and nuclear (Jaszczur et al. 2016) as well as from fossil fuels through reforming or gasification". Also figure 6.25 is updated to have a more general block for input to electrolysers.	Dong-Woon NOH	Korea Energy Economics Institute	Republic of Korea
42963	60	17	60	34	I think that paragraph 6.4.4.1 “Hydrogen: Low-Carbon Energy Fuel” need to be revised and updated for SOD-Draft. In particular the phrase starting “Hydrogen can be produced from different processes including…” I suggest to read and include consideration and data analyzed in the report prepared by the IEA for the G20, Japan: “The Future of Hydrogen Seizing today’s opportunities” [June 2019; “Chapter 2: Producing hydrogen and hydrogen-based products” p.37; available at <https://www.iea.org/hydrogen2019/> and <https://webstore.iea.org/download/direct/2803>].	This section has been revised and updated based on the IEA report on future of hydrogen, 2019: "Hydrogen can be produced from fossil fuels, biological material and water (Dodds et al 2015). To produce hydrogen with low carbon footprint following processes can be utilised: (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), and (d) from low/zero carbon energy sources such as renewables and nuclear (e.g., High Temperature Reactors (HTR) (Jaszczur et al. 2016)) in an electrolysis process (Schmidt et al. 2017). Hydrogen production costs has regional variations and it is dependent on many factors such as price of fossil fuels, electricity, and carbon (IEA 2019). In Table 6.74, the characteristics of different hydrogen production processes and estimated costs via fossil fuels are presented (CCC 2018). For natural gas reforming, the CCS will add on average 50% on the CAPEX and 10% for fuel as well as 100% of OPEX, while for coal gasification, the CAPEX and fuel cost is expected to increase 5% and OPEX by 130% (IEA 2019; Staffel et al 2019). "	MARIO VALENTINO ROMERI	Independent consultant	Italy
20767	60	18			"autothermal reforming (ATR) (Luo et al. 2014)," information about ATR cannot be found in the referenced paper Luo et al. 2014	This error is due to mixing up of the referernces. So all references are updated now.	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	China
37855	60	18			autothermal reforming: Please clarify the primary energy input to this process	It is natural gas (in table 6.74 it is shown as adavnced gas reforming)	Gunnar Luderer	Potsdam Insittute for Climate Impact Research	Germany
37403	60	19	60	20	Electrolysis is not unique to renewable energy generation. - it would include any other non-emitting energy sources.	The text has been amended accordingly: "and (d) from low/zero carbon energy sources such as renewables and nuclear (e.g., High Temperature Reactors (HTR) (Jaszczur et al. 2016)) " and "low/zero carbon generation technologies such as Renewable Energy Resources (RES) (Kraemer 2018) and nuclear (Jaszczur et al. 2016) as well as from fossil fuels through reforming or gasification". Also figure 6.25 is updated to have a more general block for input to electrolysers.	Michiel Schaeffer	Climate Analytics	Netherlands
39185	60	19	60	20	Electrolysis could also be low-carbon if it came from nuclear power, not just renewables.	The text has been amended accordingly: "and (d) from low/zero carbon energy sources such as renewables and nuclear (e.g., High Temperature Reactors (HTR) (Jaszczur et al. 2016)) " and "low/zero carbon generation technologies such as Renewable Energy Resources (RES) (Kraemer 2018) and nuclear (Jaszczur et al. 2016) as well as from fossil fuels through reforming or gasification". Also figure 6.25 is updated to have a more general block for input to electrolysers.	Tom Brown	Karlsruhe Institute of Technology	Germany

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
12901	60	21	60	21	One of the possible processes for large scale Hydrogen Generation is by thermo chemical processes using Heat from nuclear High Temperature Reactors (HTR). Substantive work has been carried in this connection in India and elsewhere. Large scale deployment of HTRs, which are themselves GHG emission free as they use nuclear energy to produce Hydrogen, the future clean energy carrier could be a key driver to the future of Hydrogen economy.	The text has been amended accordingly: "and (d) from low/zero carbon energy sources such as renewables and nuclear (e.g., High Temperature Reactors (HTR) (Jaszczur et al. 2016)) " and "low/zero carbon generation technologies such as Renewable Energy Resources (RES) (Kraemer 2018) and nuclear (Jaszczur et al. 2016) as well as from fossil fuels through reforming or gasification". Also figure 6.25 is updated to have a more general block for input to electrolysers.	ASHOK NEMA	Nuclear Power Corporation of India Limited	India
17711	60	22	60	22	To what extent does the electrolysis figure depend on the cost of ythe electricity? Presumably, the entry point at least would be utilising periods of excess renewables at almost zero marginal electricity cost?	The relevant text has been added: According to [IEA2019], the production cost of hydrogen through electrolysis process is related to the electricity price and operating hours. For more information pls see the IEA report on the future of hydrogen (Chapter 2, page 48)	Michael Grubb	UCL - Institute of Sustainable Resources	United Kingdom (of Great Britain and Northern Ireland)
31465	60	22	60	22	I do not like different currencies in one report. What about US$?	It is updated accordingly in Table 6.74 and 6.75	Patrick Jochem	German Aerospace Center (DLR)	Germany
42965	60	22	60	22	I think that “Table 6.74 Key performance and cost characteristics of different hydrogen production technologies” need to be revised and updated for SOD-Draft. I suggest to read and include consideration and data analyzed in the report prepared by the IEA for the G20, Japan: “The Future of Hydrogen Seizing today’s opportunities” [June 2019; “Chapter 2: Producing hydrogen and hydrogen-based products” p.37; available at <https://www.iea.org/hydrogen2019/> and <https://webstore.iea.org/download/direct/2803>], the Report prepared by IRENA for the 2nd Hydrogen Energy Ministerial Meeting in Tokyo, Japan “Hydrogen: A renewable energy perspective” [September 2019, available at <https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Sep/IRENA_Hydrogen_2019.pdf>], and the M. Wörsdörfer (IEA) presentation: “The Future of Hydrogen” [November 2019; Hydrogen production costs 2018, slide 6; available at <https://www.fch.europa.eu/sites/default/files/4%20-%20Session%20IV%20-%20Woersdoerfer%20%28ID%207452326%29.pdf>].	This section has been revised and updated based on the IEA report on future of hydrogen and the CCC report on hydrogen in a low carbon economy and also table 6.75 is also added to this section.	MARIO VALENTINO ROMERI	Independent consultant	Italy
9559	60	22	60	23	no ranges for electrolysis in T 6.74. This seems hard to believe, if only considering the varying price of electricity input, which can be extremely low in case of utilizing excess production from solar or wind power.	Table 6.75 is added to provide a better insight on the ranges of costs and efficiencies on different electrolysis technologies.	Tom Kram	PBL (Fellow)	Netherlands
17011	60	22	60	23	It is adviced that the key performance and cost characteristics of different hydrogen production technologies without CCS also should be listed so as to make the comparisons.	The table has been updated and all with CCS are provided to have low carbon foot print. Also the following text is added: "For natural gas reforming, the CCS will add on average 50% on the CAPEX and 10% for fuel as well as 100% of OPEX, while for coal gasification, the CAPEX and fuel cost is expected to increase 5% and OPEX by 130% (IEA 2019; Staffel et al 2019). "This actually indicates how the costs would be without CCS.	Qing YANG	Harvard University	China
20391	60	22	60	23	Table 6.74: latest cost insights are available for hydrogen supply based on renewable electricity: https://doi.org/10.1016/j.jclepro.2019.118466	A separate table on electrolysis and different technologies is provided (Table 6.75) and the relevant text and mentioned reference is added: "Three main electrolysis technologies are; alkaline electrolysis, proton exchange membrane (PEM) electrolysis, and solid oxide electrolysis cells (SOECs), where the estimated CAPEX and efficiencies are provided in Table 6.75 (IEA 2019; Fasihi and Breyer 2020). According to (IEA 2019), the production cost of hydrogen through electrolysis process is dependent to the electricity price and operating hours."	Christian Breyer	LUT University	Finland
29461	60	22	60	23	Table 6.74 states "CO2 capture rate (%)". A rate represents a quantity per unit time. "Capture fraction" or similar term would be more accurate.	For more clarification we updated Table 6.74 and added a column on carbon intensity instead of carbon capture rate to have the values on the same basis.	Eve Tamme	Global Carbon Capture and Storage Institute	Belgium
29463	60	22	60	23	Capture fractions (column 3) are given as 90% (SMR + CCS) and 96% (ATR + CCS). These lines are not comparing on the same basis. All else being equal, one would expect to see better economics for higher capture fraction - and indeed that's what we see in column 4. This is partly the effect of economies of scale rather than technology. It would be more useful to have an apples-with-apples comparison - using the same capture fraction for SMR + CCS and ATR + CCS. This would make it a technology comparison without muddying the picture with questions of scale.	Table 6.74 has been revised and updated based on the IEA report on future of hydrogen and the CCC report on hydrogen in a low carbon economy to be on the same basis and a column on Carbon intensity is added to the table.	Eve Tamme	Global Carbon Capture and Storage Institute	Belgium

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
37857	60	22			please add column on CO2 emissions intensity per GJ	A column based on kgCO2/kgH2 on carbon intenisty is added in table 6.74.	Gunnar Luderer	Potsdam Insttitute for Climate Impact Research	Germany
18709	60	28	60	28	employing SMR/ATR in the long-run' - consider removing 'in the long-run'	This point is adressed.	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
29443	60	35	61	38	Production of hydrogen from electrolysis will result in offset of renewable energy for electricity production.	This point is added to the text:"). If renewable electricity production were to be used for remote production of hydrogen, this would reduce the overall costs of grid connection and challenges associated with integration of intermittent renewable generation (such as wind curtailment), but from the other side this will result in offset of electricity generation from renewables. "	Eve Tamme	Global Carbon Capture and Storage Institute	Belgium
39191	60	36	60	36	“Seciton” → “Section”	This point is adressed.	Tom Brown	Karlsruhe Institute of Technology	Germany
31467	60	38	60	38	Please include “(such as curtailment)” at the end of this sentence.	This point is adressed.	Patrick Jochem	German Aerospace Center (DLR)	Germany
16677	60		65		A subsection about heat transport would be welcome.Reducing losses in energy transport is a challenge to be considered.	Here the focus was on energy transport through hydrogen, and hence heat transport, which is mainly realted to the end-users seems to be away from our focus.	Jean Louis Bobin	Sorbonne universités Paris	France
20769	60				wrong of the number of table 6.74	The table is updated.	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	China
20771	60				In efficiency of the hydrogen production maybe too high in table6.74	The table is updated and also Table 6.75 is added.	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	China
20773	60				table6.74. the cost of hydrogen production by electrolysis is depending on the cost of electricity, which is very different by source. so it's not suitable to use exact number here without explaintion of the electricity price.	The table is updated to provide a better insight on the ranges of costs and efficiencies and and this phrase is added to the text: "Hydrogen production costs has regional variations and it is dependent on many factors such as price of fossil fuels, electricity, and carbon (IEA 2019). "	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	China
10151	61	6	61	19	Chapter 6.4.4.1 Hydrogen: Low carbon Energy Fuel. This paragraph about hydrogen transport and distribution does not reflect present day knowledge and status. Natural gas transport pipelines can be reused in most cases to transport hydrogen. These, mostly carbon steel, pipelines can be reused within adaptations, only the compressors needs to be replaced, because the existing natural gas compressors are not suitable to compress hydrogen. And indeed a kubieke meter of hydrogen contains one third of the energy content of a kubieke meter of natural gas. But the natural gas pipelines can still transport the same amount of energy by hydrogen as by natural gas. Because hydrogen is the lightest element the flow speed in the pipeline can be increased with a factor of three before the flow becomes turbulent. Therefore the same amount of energy can be transported and no additional pipeline capacity is therefore needed. Also and therefore the comment about linepacking and maintaining the security of suplly is more challenging, is simple not true. But in any case linepacking has only a minor role in securing supply. There is a large storage capacity in salt caverns for hydrogen, which can tackle all these security of supply issues. In the Netherlands and Germany natural gas transport pipelines the national gas grid companies will convert part of there national gas grid inot a hydrogen transport grid in the next decade. Also other European countries,like the UK and Italy will follow soon. See Gasunie. (2019). Retrieved from https://www.dewereldvanwaterstof.nl/gasunie/infrastructuur/ and Stratmann, K. (2020, January 28). energiewende-gasnetzbetreiber-legen-plan-fuer-deutschlandweites-wasserstoffnetz-vor. Retrieved from Handelsblatt: https://www.handelsblatt.com/politik/deutschland/energiewende-gasnetzbetreiber-legen-plan-fuer-deutschlandweites-wasserstoffnetz-vor/25476674.html Therefore no additional new pipeline is required at first, and a fast transition to hydrogen is therefore possible, without high infrastructure cost or long time periods to realize new infrastructure.	Thanks for the comment - we checked the Gasunie references. As mentioned there, a 12km pipe is used to transport hydrogen instead of natural gas. However it is mentioned in order to transport hydrogen in medium and high pressure networks, reinforcements in compressor stations as well as some construction routes for the pipelines is required which modifying the exisiting infrastrucutr could cost 1.5 billion euros in Netherland. The relevant text is added: "Gasunie (Gasuine 2019) in Netherlands has used an existing 12km natural gas pipeline for transporting hydrogen. On the other hand, new pipelines for hydrogen transmission at national level are likely to be required. In order to transport hydrogen in medium and high pressure networks, reinforcements in compressor stations as well as some construction routes for the pipelines is required (Gasuine 2019). "	Ad van Wijk	Technical University Delft	Netherlands

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
18711	61	13	61	13	Therefore, maintaining the security of supply is more challenging in hydrogen networks, and hence linepack (Dragoni 2017; Amiryar and Pullen 2017) will play a critical role. (Linepack is the volume of hydrogen stored in the pipelines and can be used to meet abrupt diurnal changes in hydrogen demand.)' - Having checked the reference Amiryar and Pullen 2017 - this does not discuss linepack . I cannot download the Dragoni reference, but imagine this is focussed on flywheels too - and does not mention linepack in gas systems. A relevant publication could be https://doi.org/10.1016/j.ijhydene.2013.03.070 Dodds and Demoulin, Conversion of the UK gas system to transport hydrogen, 2013.	This error is due to mixing up of the referernces. So all references are updated now.	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
18713	61	15	61	19	As presented in (Taylor et al. 2012) in the Iron Mains Replacement Programme, the existing low pressure gas distribution pipes are being converted from iron to plastic for health and safety reasons. This new distribution gas infrastructure will be able to transport hydrogen within districts (over short distances). On the other hand, new pipelines for hydrogen transmission at national level are likely to be required.' - this is currently very UK focussed. It would be worth considering a more generic statement such as 'For countries that already have a significant natural gas delivery infrastructure, there is growing interest in exploring whether this can be repurposed to transmit and distribute hydrogen to end users.'	The text has been amended accrodingly:"For countries that already have a significant natural gas delivery infrastructure, there is growing interest in exploring whether this can be repurposed to transmit and distribute hydrogen to end users. As an example 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. This new distribution gas infrastructure will be able to transport hydrogen within districts (over short distances). "	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
20775	61	15			"As presented in (Taylor et al. 2012) in the Iron Mains Replacement" Two "in"	The point is addressed	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	China
31469	61	16	61	16	You may mention the environmental impact from plastic here. Furthermore, the additional pressure of H2 might be problematic.	we added in the text this replacement programm will have also enviromantal impacts. Furthermore as provided in the text, through this replacement the hydrogen is transported without any issues:"For countries that already have a significant natural gas delivery infrastructure, there is growing interest in exploring whether this can be repurposed to transmit and distribute hydrogen to end users. As an example 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. This new distribution gas infrastructure will be able to transport hydrogen within districts (over short distances). "	Patrick Jochem	German Aerospace Center (DLR)	Germany
10141	61	20	61	29	Chapter 6.4.4.1 Hydrogen: Low carbon energy fuel. In this alinea key challenges for hydrogen transport are mentioned such as delivery cost, energy efficiency, ... The fundamental discussion is about energy system efficiency versus energy system cost. And in a sustainable energy system it is not about system efficiency but about system cost. In the book 'Solar Power to the People' https://www.alliedwaters.com/wp-content/uploads/2017/11/Solar-Power-to-the-People-EN.pdf (see page 62) a cost comparison is made betwen the cost of producing in Northern Europa with solar panels on the roof of a house 100 kWh electricity versus delivering the same amount of electricity, 100 kWh by producing electricity in the Sahara dessert with large scale solar PV farm, converting to hydrogen, making the hydrogen liquid, ship it to Europa, put it in a pipeline and convert the hydrogen into electricity using a fuel cell. It turns out that the cost for these 100 kWh electricity is the same, but the advantage is that this 100 kWh could be delivered at every moment, day and night, summer and winter. And of course in the dessert 255 kWh of electricity has to be produced to deliver 100 kWh at the house, a system efficiency of less than 40%. And in the dessert the same number of solar modules were necessary to produce this 255 kWh than on the roof of the house to produce 100 kWh, because in the dessert the irradiation is 2.5-3 times higher than in Northern Europe. That is also the reason that system efficiency has no longer a meaning in a sustainable energy system, it is all about system cost!	Thanks for the comment. This is absolutly correct. we changed energy efficiency to system cost.	Ad van Wijk	Technical University Delft	Netherlands

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
10153	61	20	61	29	Chapter 6.4.4.1 Hydrogen: Low carbon energy fuel. In this paragraph the conclusion is formulated 'currently a global hydrogen-based economy is not considered feasible unless as appropriate storage medium could be established' There is many evidence that a hydrogen-based economy is feasible, as is reported in studies already mentioned in above comments. The statement here is unless an appropriate storage medium could be established, whereby salt caverns are mentioned to have many challenges from techno-economic perspective. But salt caverns are already in use for hydrogen at several places in the world. Since 1972 near Leeds for example, so it is already a very mature and old storage technology for hydrogen with no technological challenges. An average salt cavern can store between 3.000 and 6.000 ton hydrogen, which is between 120 and 240 GWh. The installation cost needed for compression, cleaning, etc. are about 100 million Euro, seeMichalski, J., Bünger, U., Crotogino, F., Donadei, S., Schneider, G., Pregger, T., & al, e. (2017). Hydrogen generation by electrolysis and storage in salt caverns: Potentials, economics and systems aspects with regard to the German energy transition. International Journal of Hydrogen. But if this same amount of energy would be stored in batteries at a very low cost of 100 Euro/kWh than total investment cost would be between 12-24 billion Euro. So also economically hydrogen storage in salt caverns is at least a factor of 100 cheaper than storage in batteries. The question could be is there enough storage capacity in salt caverns available? That have been studied recently, by Jülich Caglayan, D., Weber, N., Heinrichs, H., Linßen, J., Robinius, M., Kukla, P., & Stolten, D. (2020). Technical Potential of Salt Caverns for Hydrogen Storage in Europe. International Journal of Hydrogen Energy. This study was for Europe, but the conclusion is that dedicated salt caverns can be made for hydrogen storage, with a potential capacity of more than the total energy demand of the Europe. Also in other parts of the world salt formations are present to store hydrogen in salt caverns. So cheap storage of hydrogen, especially in salt caverns, is one of the key advantages of hydrogen and to establish a hydrogen economy.	The required text and references are added and it is mentioned that the limitation is they are not suitbale for short term and small scale storage (IEA 2019):"currently from an economic point of view a global hydrogen-based economy is not considered feasible unless an appropriate storage medium, which can provide from short to long term could be established. For direct large-scale hydrogen storage, mediums such as salt caverns (Andersson and Grönkvist 2019; Jülich et al 2020) and hydrides (Züttel and Schlapbach 2001) has been investigated, however there are still many challenges from techno-economic perspective, due to large size and minimum pressure requirements of sites (IEA 2019), which makes them not suitable for small scale and short term storage purposes."	Ad van Wijk	Technical University Delft	Netherlands
31471	61	23	61	23	Please integrate “from an economic point of view” in front of “currently”.	This point is adressed.	Patrick Jochem	German Aerospace Center (DLR)	Germany
34395	61	29	60	11	Please add: Artz et al., 2019 has 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 in so called “Power-to-fuel” scenarios. (Artz et al., 2019: Sustainable Conversion of Carbon Dioxide: An Integrated Review of Catalysis and Life Cycle, Assessment, Chem. Rev., 118, 2, 434-504)	The relevant reference is added:" (Artz et al. 2019) has 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 in so called “Power-to-fuel” scenarios. "	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
10143	61	30	63	4	Chapter 6.4.4.2 Ammonia, promising hydrogen carrier. Ammonia is indeed a promising hydrogen carrier for transport by ship. But also the LOHC's, whereby hydrogen is bound to a carrier, f.e. toluene is promising. The Japanese company Chiyoda builds a fully integrated supply chain for this https://www.energy.gov/sites/prod/files/2018/10/f56/fcto-infrastructure-workshop-2018-32-kurosaki.pdf The main advantage is that it is a liquid, which can be transported by oil tankers and stored in oil tanks, so the oil infrastructure can be re-used. And when the dehydrogenation can be done at a chemical site, where excess heat is available, this can be a cost effective hydrogen transport chain. And liquid hydrogen transport will emerge also. Kawasaki is building the total supply chain. http://global.kawasaki.com/en/stories/hydrogen/index.html The interesting thing is that the boil off could be used to fuel the fuel cell in the liquified hydrogen carriers(ships and trucks) So the losses are used. Hydrogen fueling stations will get their hydrogen by a liquid hydrogen transport infrastructure, ships and trucks, which is considerable cheaper than transport by truck of compressed hydrogen. Check some literature too, about this subject, f.e. Reuss, Grube, Robinius, Preuster, Wasserscheid, Stolten; Seasonal Storage and alternative carriers: A flexible hydrogen supply, Applied Energy 200 (2017) 290-302, and Heuser, Severin Ryberg, grube, Robinius, Stolten; Techno-economic analysis of a potential energy trading link between Patagonia and Japan based on CO2 free hydrogen, International Journal of Hydrogen Energy 44(2019) 12733-12747 However, the most cost-efficient way to transport hydrogen is in its gaseous form by pipeline, and there really no issues with linepacking(see before), maintaining hydrogen purity (can made as pure as you want by PSA (Pressure Swing Absorption) or electrochemically (HyET’s Electrochemical Hydrogen Purification and Compression (EHPC) https://hyethydrogen.com/)	The text is improved and the following text is added: "The main advantage is that LOHCs have similar properties to oil products, and hence they can be transported by oil tankers and stored in oil tanks, so the oil infrastructure can be re-used. A project is under development in Brunei to export hydrogen to Japan using LOHCs (Kurosaki 2018). One of the potential LOHCs is methylcyclohexane (MCH), with toluene as the carrier molecule. However toluene is toxic, and an alternative LOHC is dibenzyltoluene, which is much more expensive than toluene currently (IEA, 2019)."	Ad van Wijk	Technical University Delft	Netherlands

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
37859	61	30			This section 6.4.4.2 is not only about ammonia, but various ways of liquifying H2. It would be helpful to provide an overview table of alternative approaches, including coversion efficiencies and energy densities.	A new table including the denisty and costs is added (Table 6.76). Besides , in order to achieve low/zero carbon targets, a statement on continuing use of natural gas or synthetic fuels (carbon-based) through introducing negative emission technologies such as biomass with CCS and direct air capture is presented. The following text is added: "Hydrogen could be used with captured CO2 to produce synthetic fuels (Power-to-X) such as ammonia, methanol, synthetic methane, and synthetic oil products (IRENA 2019). Such alternative fuels are drop-in solutions to move away from fossil fuel as: (a) it can be used in existing infrastructure in the intensive industries and in the transport sector (Gumber and Gurumoorthy 2018; Schemme et al. 2017; Transport & Environment 2018; DENA 2017), (b) can benefit from the liquefied natural gas (LNG) industry, and (c) easier storage for hydrogen (IRENA 2019). In the transport sector, synthetic methane 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 CO2 based fuels (Gumber and Gurumoorthy 2018). On the downside, if the CO2 is captured from fossil fuel combustion process, there are still CO2 emissions and this is not in line with the Paris climate objectives. Hence, to abate the greenhouse gas emissions, the CO2 should be captured from biomass or from direct air capture (DAC) technologies (IRENA 2019). DAC is a costly technology; however, the projection is to reach below 60 USD/tCO2 in 2040 (Fasihi et al. 2019). "	Gunnar Luderer	Potsdam Insttitute for Climate Impact Research	Germany
18715	61	40	61	40	processes (~180 mtonnes/year' - it is worth writing the million tonnes out in full to avoid confusion with different methods of indicating a million or a thousand tonnes	This point is adressed.	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
9561	61	42	61	44	Difference between coal and gas look suspiciously small, given the carbon content per unit of energy of the two fuels and even more taking the gasification step into account.	we checked again the references, and the values are as it is stated.	Tom Kram	PBL (Fellow)	Netherlands
31473	62	3	62	3	Please integrate storage in this nice figure! This is the main advantage of H2/Ammonia – isn't it? I would at least set "Natural gas" and "Coal" in brackets or delete it. Why should we use NG or coal if we have sufficient wind? (Currently you display a transition situation here!)	The figure has been update with adding storage to that. Also coal is put in brackets.	Patrick Jochem	German Aerospace Center (DLR)	Germany
10145	62	23	63	4	Chapter 6.4.4.2 Ammonia, promising hydrogen carrier. Ammonia can be used in diesel engines but ammonia can be used also in high temperature fuel cells, the Solid Oxide Fuel Cell, whereby both electricity and hydrogen can be produced without any nitrogenoxide emissions. Or ammonia can be used in an alkaline low temperature fuel cell, Gencell is company that produces these fuel cell (https://www.gencellenergy.com/gencell-technology/the-gencell-advantage/)	The relevant text is added:Ammonia can be used also in low and high temperature fuel cells (Lan and Tao 2014), whereby both electricity and hydrogen can be produced without any NOx emissions.	Ad van Wijk	Technical University Delft	Netherlands
2617	62	26	62	27	"Ammonia is considered a carbon-free sustainable fuel for power generation, since in a complete combustion, only water and nitrogen are produced". This is not entirely true; in practice significant quantities of nitrogen oxides (NOx) are also generated. These gases contribute to the formation of smog and acid rain, as well as affecting tropospheric ozone.	This is mentioned already in the text. it is carbon-free, and as mentioned in the text, furthermore it is also added that it can cause also visibility pollutions: "a key challenge in use of ammonia is NOx emissions (released from nitrogen and oxygen combustion) and unburned ammonia, which are a substantial air pollution risk, not only from a health perspective (toxicity) but also from visibility perspective (EPA, 2001). To deal with NOx emissions, a special catalyst would be adapted to combine ammonia with nitrogen to decrease the nitrogen oxides production (Bicer and Dincer 2018). "	Michael Czerniak	Atlas Copco - Edwards	United Kingdom (of Great Britain and Northern Ireland)
18717	62	32	62	32	As a co-author of the referenced paper - Barbour et al, 2016, there is no mention of ammonia throughout the paper. So - this seems like an error. A suitable paper could be: Science and technology of ammonia combustion, Kobayashi et al. 2019 https://doi.org/10.1016/j.proci.2018.09.029	This error is due to mixing up of the referernces.	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
6387	62	34	62	34	It seems there is an issue with references. For example here the reference 'Highview Power 2019' is not related to flammability/ignition of ammonia	This error is due to mixing up of the referernces. So all references are updated now.	Sciacovelli Adriano	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
18719	62	34	62	34	The highview power link seems a little out of place as a industry website page. Also - the technology is not focussed on ammonia, it is a liquid air technology for storage. This reference may be an error.	This error is due to mixing up of the referernces. So all references are updated now.	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
31475	63	1	63	4	This section is very vague. Furthermore, you may refer to concrete LCA values from specific references when you highlight the GHG emissions.	To avoid confusion the second paragraph has been removed (about micro algae). Furthermore, about the valuses of GHG emissions, this is provided already in the text in the previous section: ". The life cycle assessment (LCA) of ammonia production methods through fossil fuels is demonstrated in (Singh et al. 2018). If ammonia is produced from biomass (gasification), the GHG emissions is 0.38 kg CO2 eq./kg NH3, while from natural gas (SMR method) and coal (gasification) it is 3.03 and 3.85 kg CO2 eq./kg NH3, respectively. "	Patrick Jochem	German Aerospace Center (DLR)	Germany
10155	63	6	63	16	Chapter 6.4.4.3 Challenges around hydrogen energy fuels. It is stated here that all hydrogen energy carriers need to resolve issues around flammability, toxicity and safe storage. But Hydrogen is not toxic!!!, safe storage in salt caverns is already in use since decades, Flammability, indeed hydrogen needs less ignition energy and a mixture of hydrogen and air with hydrogen concentrations as low as 4.1 vol% and as high as 74 vol%, can ignite. For natural gas these specifications are, from a safety perspective, better. However, hydrogen has another property, that makes it even more safer than natural gas. Hydrogen is the lightest and smallest element, when hydrogen is released into the air under atmospheric pressure it raises with 20 m/s. And because it is a the smallest element, it escapes even out of a well insulated house. So hydrogen is already gone, before it can mix with air and can ignite. And burning hydrogen has another safety advantage, it can never produce CO Carbon monoxide, that still kills and injures many people in the world.	For clarificaition a foot note is added about hydrogen it self: "For hydrogen, there is no issue about toxicity and safe storage (in salt caverns)"	Ad van Wijk	Technical University Delft	Netherlands
27943	63	6	63	16	Please clarify that a risk of using ammonia is that ammonia leaks are a substantial air pollution risk, not only from a health perspective but also a visibility perspective. The greatest visibility reducing pollutant in the eastern Los Angeles basin is ammonium nitrate, which combines ammonia (dissolved as the ammonium ion) with nitric acid (dissolved as the nitrate ion). Ammonia is not recommended for a clean, renewable energy future.	The visibility issue and a references is also added in the text:"a key challenge in use of ammonia is NOx emissions (released from nitrogen and oxygen combustion) and unburned ammonia, which are a substantial air pollution risk, not only from a health perspective (toxicity) but also from visibility perspective (EPA, 2001). "	Mark Jacobson	Stanford University	United States of America
18721	63	12	63	12	As a co-author of the referenced paper - Barbour et al, 2016, there is no mention of ammonia throughout the paper. So - this seems like an error. A suitable paper could be: Science and technology of ammonia combustion, Kobayashi et al. 2019 https://doi.org/10.1016/j.proci.2018.09.029	This error is due to mixing up of the referernces. So all references are updated now.	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
5723	63	17	63	24	This paragraph is not contextualised at all, and makes no sense here.	To avoid confusion the second paragraph has been removed (about micro algae).	paul fennell	Imperial College	United Kingdom (of Great Britain and Northern Ireland)
15711	63	17	63	24	This paragraph is confusing and requires more context and development, e.g. how microalgae can be used as a feedstock for hydrogen fuels (?) In the feedstock comparison compared to H2 made from methane using SMR/ATR?	To avoid confusion the second paragraph has been removed (about micro algae).	CHRISTOPHER BATAILLE	IDDRI.ORG/SIMON FRASER UNVIERSITY	Canada
17013	63	22	63	24	I suggest to clarify what kinds of limitations the microalgea technologies face now.	To avoid confusion the second paragraph has been removed (about micro algae).	Qing YANG	Harvard University	China
8825	63	25	63	25	This paper could be of interest: https://www.nature.com/articles/s41597-019-0347-4	Add to first sentence, line 26, page 63: "as does the scale of transmission network available to harness these resources (Aderne et al. 2020)."	Saygın Değer	SHURA Energy Transition Center	Turkey
8825	63	25	63	25	This paper could be of interest: https://www.nature.com/articles/s41597-019-0347-4	To avoid confusion the second paragraph has been removed (about micro algae).	Saygın Değer	SHURA Energy Transition Center	Turkey
5651	63	25	65	47	There are strong counterarguments in the academic literature to the general position expressed in this section that huge investments in transmission are needed and would help cost-effectively decarbonize the power sector. Actually, the following two references argue that this idea is now obsolete given the steep recent cost declines in renewable electricity technologies. As these technologies have gotten so much cheaper, it could be more cost-effective to locate them closer to the loads they serve, even if the resource quality is lower, and avoid transmission investments. These counterarguments should at least be acknowledged and discussed. Lovins, A.B., 2017. Reliably integrating variable renewables: Moving grid flexibility resources from models to results. The Electricity Journal 30, 58-63. Jayadev, G., Leibowicz, B.D., Kutanoglu, E., 2020. U.S. electricity infrastructure of the future: Generation and transmission pathways through 2050. Applied Energy 260, 114267.	Add to line 15, page 64: "Transmission infrastructure is not the only solution for enhancing renewables uptake, with (Lovins 2017) and (Jayadev et al 2020) arguing that, for example, in the USA further investment in e.g. localised storage may be preferable to larger-scale transmission investments."	Benjamin Leibowicz	The University 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
15715	63	25	65	47	The whole section on electricity transmission 6.4.4.4. needs to be clarified, starting with why transmission is important,what role does it play in energy service delivery and GHG mitigation, etc (e.g. for VRE balancing). The section on north/south Europe is a good embarcation point for explaining many of these issuse.	See other amendments	CHRISTOPHER BATAILLE	IDDRI.ORG/SIMON FRASER UNVIERSITY	Canada
20393	63	25	65	47	knowledge is missing on the economics of large-scale grid integration. Breyer et al. (https://www.iaee.org/eeep/article/305) provide the first global study on full grid integration on hourly resolution and do find a high regional integration potential, but limited potential for further integration. These findings are supported by Agahosseini et al. (https://www.sciencedirect.com/science/article/pii/S1364032119300504), Gulagi et al. (https://www.mdpi.com/2071-1050/9/2/233) and Child et al. (https://www.sciencedirect.com/science/article/pii/S0960148119302319) and Bogdanov et al. (https://ieeexplore.ieee.org/document/7569508) - the article of Breyer et al. provides a broad literature discussion on the topic	Add new sentence line 15, page 64 before "Also…": "An analysis of the potential benefits of global co-operation in improving reliability and ability to mitigate the consequences of global warming are given in (Breyer et al 2019) and (Bogdanov et al 2016) and imply that a globally interconnected system would improve both economic performance and reliability."	Christian Breyer	LUT University	Finland
39189	63	25	65	47	There are a lot of self-cites from Strbac's group on the benefits of electricity tranmission here. For balance include: G. Czisch, Szenarien zur zukünftigen Stromversorgung, Ph.D. thesis, Universität Kassel (2005), Schaber et al http://dx.doi.org/10.1016/j.enpol.2011.12.040, Rodriguez et al http://dx.doi.org/10.1016/j.renene.2013.10.005, Haller et al https://doi.org/10.1016/j.enpol.2012.04.069, Gils et al 10.1016/j.energy.2017.01.115, Schlachtberger et al http://dx.doi.org/10.1016/j.energy.2017.06.004, MacDonald et al 2016 (already cited)	Replace sentence beginning (references drawn from comment unless stated) "Also…" page 64, row 15 with "There is also significant research into the benefits of wider integration between MENA and the Europe for renewable energy resource sharing, for example in (Schaber et al 2012), (Rodriguez et al 2014), (Haller et al 2012), and (Gils et al 2017). There are clearly benefits to utilising continental climatic variation to share renewable energy resources (Kaspar et al 2019) and could also help support economic development in MENA regions, as well as temporal differences allowing countries to share the burden of meeting peak demand across wider geographic ranges." (Kaspar, F., Borsche, M., Pfeifroth, U., Trentmann, J., Drücke, J., and Becker, P.: A climatological assessment of balancing effects and shortfall risks of photovoltaics and wind energy in Germany and Europe, Adv. Sci. Res., 16, 119–128, https://doi.org/10.5194/asr-16-119-2019, 2019.)	Tom Brown	Karlsruhe Institute of Technology	Germany
9567	63	25			Section 6.4.4.4 only addresses large scale, HV power transmission. Much more relevant and crucial changes in local/regional distribution systems (e.g. so called smart grids) to accommodate decentral and central renewables supply and substantial rises in demand e.g. due to electrification of transport and heating of buildings.	Add new sentence line 21, page 64: "Increased interconnectivity of large-scale grids also allows the aggregation of "smart grid" solutions such as flexible demand from wet devices (Labeeuw et al 2015) or use of electric vehicles (EVs) as demand response (Rassaeie et al 2015) to support regional system performance. Larger scale integration of systems can facilitate resource sharing of such assets over wide geographic ranges." (W. Labeeuw, J. Stragier and G. Deconinck, "Potential of Active Demand Reduction With Residential Wet Appliances: A Case Study for Belgium," in IEEE Transactions on Smart Grid, vol. 6, no. 1, pp. 315-323, Jan. 2015, doi: 10.1109/TSG.2014.2357343.), (F. Rassaei, W. Soh and K. Chua, "Demand Response for Residential Electric Vehicles With Random Usage Patterns in Smart Grids," in IEEE Transactions on Sustainable Energy, vol. 6, no. 4, pp. 1367-1376, Oct. 2015, doi: 10.1109/TSTE.2015.2438037.)	Tom Kram	PBL (Fellow)	Netherlands
42011	63	25			6.4.4.4. "Electricity transmission". This section should include a detailed reference to smart grids. For "the public", smart grids are mainly known as ICT suporting thhe integration, operation and integratio of smart grids into power netwroks. But smart grids are much more than this and, in fact, are a crucial instrument for electricity transmision in general. They are instrumental in electrical power generation, transmission or distribution, in the management and operation of end-user stationary applications, also in the interaction of electric and hybrid vehicles with the electric power system (vehicle to grid arrangements, cooperative charging and interoperability).	As above	Francisco Javier Hurtado Albir	European Patent Office	Germany

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
14199	63	26	65	47	The pros of regional interconitental lines are reviewed but not the cons, notably loss of energy sovereignity, increased vulneratilibities, etc. check the following references: Vakulchuk, Roman, Indra Overland, and Daniel Scholten. "Renewable energy and geopolitics: A review." Renewable and Sustainable Energy Reviews (2020): 109547. Capellán-Pérez, I., de Castro, C., Arto, I., 2017. Assessing vulnerabilities and limits in the transition to renewable energies: Land requirements under 100% solar energy scenarios. Renewable and Sustainable Energy Reviews 77, 760–782. https://doi.org/10.1016/j.rser.2017.03.137	Add sentence to line 21 page 64: "Such developments are not without cost, however, and, amongst other concerns, raise issues surrounding land use and resource acquisition for materials necessary for renewables developments. Such issues are discussed in (Vakalchuk et al 2020) and (Cappellán-Pérez te al 2017)."	Iñigo Capellán-Pérez	University of Valladolid	Spain
9047	63	30	63	31	I don't really agree the three components are the core benefits of an transmission system expansion. I would suggest to add "mitigation of renewable variability on synoptic, seasonal and interannual scales" as this aspect is extensively discussed lateron.	Add to end of sentence, line 32 page 63: "though there are also benefits associated with mitigation of regional variations in renewable energy output over diurnal, seasonal, and interannual cycles."	Jan Wohland	ETH Zürich	Switzerland
42009	63	31			"enhanced operation efficiency (INCLUDING LOAD-GENERATION LEVELLING)"	Amend sentence line 30, page 63: "(i) enhanced security of supply (ii) enhanced operation frequency (e.g. regional load-generation levelling)..."	Francisco Javier Hurtado Albir	European Patent Office	Germany
28893	64	1	64	1	Figure 6.26. Don't forget to provide the legend	Will be amended	Marissa Malahayati	National Institute for Environmental Studies	Japan
17015	64	1	64	3	Figure 6.26 should be improved in many aspects, such as listing the order of colors, explaining that the wind resource distribution includes on-shore and off-shore, which is ignored in 6.4.2.2.	As above	Qing YANG	Harvard University	China
35731	64	1	64	3	Both figures do not have a colour legend. This could either be wind speed and solar radition, or converted to energy yield based on idealised assumptions. Similar figures, with ressource data from Europe already converted to capacity factors for direct comparison are available in https://doi.org/10.5194/asr-16-119-2019 . They are available under a free usage licence and the authors can also support modifications, if needed.	As above	Frank Kaspar	Deutscher Wetterdienst	Germany
9049	64	4	64	8	You mention the positive effect of seasonal balancing between different regions here. I agree that this is an important component but it is not the full story. Transmission is also helpful in balancing on substantially shorter and longer timeframes. I suggest to discuss the results of Monforti (2016), Schlachtberger (2017) and Rodriguez (2014). References Monforti, F., Gaetani, M. & Vignati, E. How synchronous is wind energy production among European countries? Renewable and Sustainable Energy Reviews 59, 1622–1638 (2016). Schlachtberger, D. P., Brown, T., Schramm, S. & Greiner, M. The benefits of cooperation in a highly renewable European electricity network. Energy 134, 469–481 (2017). Rodríguez, R. A., Becker, S., Andresen, G. B., Heide, D. & Greiner, M. Transmission needs across a fully renewable European power system. Renewable Energy 63, 467–476 (2014).	Addressed above	Jan Wohland	ETH Zürich	Switzerland
35733	64	4	64	8	Further studies support the statements in this section for Europe and other regions and partly provide additional arguments. E.g. https://doi.org/10.5194/asr-16-119-2019 supports the idea of large scale balancing effects in Europe, but also shows that additional benefits arise from such large scale cooperation, e.g. the reduction of shortfall risks (situations with low wind/solar availability). The paper also provides references to studies with similar results for other regions in the world (e.g. for West Africa (Sterl et al., 2018), China (Ding et al., 2017), Canada (Hoicka and Rowlands, 2011) or Brazil (De Oliveira Costa Souza Rosa et al., 2017).	Addressed above	Frank Kaspar	Deutscher Wetterdienst	Germany
16679	64	4		8	Such an analysis is highly questionable due to the intermitency of solar and wind power. Wind is radom at any timescale and does not follow a gaussian distribution. Furthermore in the winter, anticyclonic conditions happen to occur for days over the whole western Europe implying no wind power at all.	Add to end of sentence on line 8, page 64: "though there may be significant variation over diurnal cycles or associated with continental weather patterns."	Jean Louis Bobin	Sorbonne universités Paris	France
9563	64	9	64	10	Explain this, not obvious where this saving would come from	Add to end of sentence, line 10, page 64: "by, for example, harnessing of the climatic dipole between southern and northern Europe with more efficient location of renewable energy sources and maximising use of high-productivity regions. That is, put simply, building more wind in areas with high wind potential and more solar in areas with better solar connectivity and increasing transport between regions to allow effective sharing of resources."	Tom Kram	PBL (Fellow)	Netherlands

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
1541	64	15	64	19	Comment on pages 64 and 97: An example to explain the difference between the technical reduction potential (maps showed in the text) and economic and realistic potential, the Desertec project is illustrative. This project aimed to create large-scale CSP solar power plants was not successful. It failed mainly because of governance issues: political agreements between Europe and Africa are difficult, local countries were too little involved in decision making while they will receive the impacts, and existing and future conflicts were a threat for the security of energy supply. This general lack of governance is also addressed by the planetary security initiative mentioned above. Information: https://en.wikipedia.org/wiki/Desertec	Add new paragraph line 22, page 42: "There were ambitious, large-scale plans to facilitate significant international co-operation and harness the solar potential of North Africa in the Desertec project, but the project ultimately failed due to, amongst other factors, governance issues, political disagreements, and poor engagement with affected countries and communities."	Paul Vethman	PBL Netherlands Environmental Assessment Agency	Netherlands
9051	64	15	64	21	Since you mention Desertec-like project here, I wonder if you should also provide some background information about why the first attempt to make desertec happen failed.	As above	Jan Wohland	ETH Zürich	Switzerland
9565	64	22	64	36	Check these statements thoroughly, they look totally incredible with respect to purpose, role and deployment of DC versus AC connections.	N/a	Tom Kram	PBL (Fellow)	Netherlands
15713	64	22	65	16	What does this mean? "In the context of transmission network design, there is a roughly even split between Alternated Current(AC) and Direct Current (DC) technologies" Even split of market/delivery share?? In general, these transmission paragraphs need a clearer purpose, context setting and flow of arguments, as they address some very import electricity decarbonization issues, e.g. why are HVDC etc. lines important compared to the standard high voltage AC lines, etc.	Amend sentence at start of line 22, page 64: "Transmission-scale grids are constituted either of systems running in alternating current (AC) or direct current (DC), with AC…"	CHRISTOPHER BATAILLE	IDDRI.ORG/SIMON FRASER UNVIERSITY	Canada
1223	64	31			Write the full details of HVDC and HVAC	Discussed in other comments	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
9569	65	1			Check consistency and/or overlap with Chapter 5	N/a	Tom Kram	PBL (Fellow)	Netherlands
1225	65	2			Provide reference	Add to end of sentence on line 1, page 65: "(Bahrman 2003)" (Bahrman, Michael P., Jan G. Johansson, and Bo A. Nilsson. "Voltage source converter transmission technologies: the right fit for the application." 2003 IEEE Power Engineering Society General Meeting (IEEE Cat. No. 03CH37491). Vol. 3. IEEE, 2003.)	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
42365	65	5	65	5	There are several editorial problems that needs to be fixed. This is simply to show one case, which is a bit confusing. I hope you mean "weak-grid" , not "weak-gird".	Amend typo as identified. Other typoes are amended above.	Solomon Asfaw	LUT University	Finland
25077	65	46	65	47	Delete "which is currently the core barrier … of renewable generation." as this is not fully aligned with analysis presented in previous sections	Replace "which is currently…" line 46 page 65 with "which remains one of the main drivers of power system reform and redesign in Europe."	Eleni Kaditi	Organization of the Petroleum Exporting Countries (OPEC)	Austria
10905	66	1	66	1	Section 6.4.5 ondemand side mitigation options is relatively brief but could be cross-referenced against Chapter 5 to provide the appropriate level of detail without duplication.	Noted, cross references will be added	Ian Bailey	University of Plymouth	United Kingdom (of Great Britain and Northern Ireland)
17713	66	1	67	48	This covers very much what I tend to term 'first domain' decision-making, with emphasis on behavioural characteristics and corresponding 'first pillar' policies (Grubb, Hourcade and NEuhoff (2014), Planetary Economcis Chapters 4 & 5) to overcome and the 'web of constraints' impeding more efficient use and being more resopnsive. This section could usefully coordinate more directly with parts of Chapter 5?	Noted, cross references to Chapter 5 will be added	Michael Grubb	UCL - Institute of Sustainable Resources	United Kingdom (of Great Britain and Northern Ireland)
11507	66	1	68	9	It seems to lack of the block-chaine as disruptive demand side managemnt system. And It should be focused on the presense of 'prosumer' as agrregating consumer aswell. The form of transaction is dramatically changing by emerging of block chaine. Moreover, these innovation and businesses are prodoced at cluster level such as Silicon Valley in the US or Shenzhen in China. These movement have both positive and negative aspects. Bloch-chaine can acceralate the B to C transaction of renewable energy, on the other hand block chaine consume a large number of energy in the process of mining. Either way, This disruptive demand-side innovation will bring a dramatical change to energy sector in the context of climate mitigation.	Noted. Prosumer behaviour is covered in the first bullet points. Space restrictions inhibit us to discuss block chains in detail (chech - is this covered in Ch5 or other chapters?	Muneki Adachi	University	Japan
43689	66	1			Nice section! Maybe to add: User adoption may be key driver of bringing technologies into markets. Check out Greg Nemets recent book.	Taken into account, will be added when possible within word count	Felix Creutzig	MCC Berlin	Germany
31477	66	2	66	7	You may distinguish here very clear between (1) user acceptance and Demand Side Management. For me this difference is not clear enough in this paragraph.	Accepted. Section 6.4.5 focuses on demand side management, so behaviour change. Acceptability of options is discussed when assessing the relevant options and in 6.7.6.2 - we clarified this in the first paragraph of 6.4.5	Patrick Jochem	German Aerospace Center (DLR)	Germany
43579	66	8	66	13	prosumer solutions for end users are can be PV based and cover electricity, heat and mobility - as analysed in detail be Keiner et al. (https://www.sciencedirect.com/science/article/pii/S0038092X19304281)	Noted, this is covered in the next bullet point, line 14-19	Christian Breyer	LUT University	Finland
11109	66	8	66	32	add following sentences; "Energy users can adopt appliances and systems that use electricity (e.g. space heating, cooking, and providing hot water) instead of fossil fuels "	Accepted. We added that people could adopt low energy carriers, as electrification would only reduce GHG emissions when electricity is produced with low carbon energy sources .	Midori Sasaki	industrial organization	Japan

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
37861	66	8			This list should also include that end users can switch from fossil to low-carbon energy carriers, e.g. electricity, hydrogen and bioenergy. Electrification is particularly important against the backgroupd of a rapidly decarbonizing power sector.	Accepted, adoption of low carbon energy carriers is added in the first bullet	Gunnar Luderer	Potsdam Insttitute for Climate Impact Research	Germany
8903	66	10	66	11	You state: "People can use renewable energy sources with low carbon emissions." This is true and interesting as long as the electricity supplied by the network is produced by fossil fuels. If electricity distributed by the network is low carbon content (hydro or nuclear), the investment is not justified.	Accepted, this is indicated later in the sentence: people can either produce renewable energy themselves, purchase shares in renewble energy projects or select a renewable energy provider. We added the adoption of low emission energy carriers	Michel SIMON	Vice Président SFENRAL	France
31479	66	11	66	11	You may include “(e.g. use wood pellets for heating)”. You may replace “produce” by “use”.	Accepted, use is added. We did not add the use of wood pellets - due to space restricitions we only mention the most sustainable options (wood pellets are associated with emissions of CO2)	Patrick Jochem	German Aerospace Center (DLR)	Germany
42035	66	12			Heat pumps in general are referred. Perhaps a reference to aerothermy and geothermal pumps should be made	Noted, space limitations inhibit us from discussing this in detail I guess this is discussed elsewhere in AR6, if so, we can add cross reference	Francisco Javier Hurtado Albir	European Patent Office	Germany
15717	66	14	66	19	Vogl al 2018 has sections on how hydrogen steel making, and specifically hydrogen making during high VRE production and low demand, can provide demand response to the electricity system. Vogl, V., Åhman, M., & Nilsson, L. J. (2018). Assessment of hydrogen direct reduction for fossil-free steelmaking. Journal of Cleaner Production, 203, 736-745.	Noted, this section focuses on end users, this notion is more relevant for the Industry chapter	CHRISTOPHER BATAILLE	IDDRI.ORG/SIMON FRASER UNVIERSITY	Canada
31481	66	14	66	19	You may mention “Demand Response” or “Demand Side Management” here explicitly. Why is here no reference for this bullet point?	Noted, demand side management has been defined differently in the literature (eg reduction of demand vs matching demand and supply). To avoid confusion and misinterpretation, we therefore describe the specific actions	Patrick Jochem	German Aerospace Center (DLR)	Germany
39197	66	14	66	19	The use of demand side management from other sectors, such as charging shifting for battery electric vehicles or power-to-heat combined with building thermal inertia or thermal energy storage, needs more space here.	Noted, these notions are discussed in the sections on energy systems	Tom Brown	Karlsruhe Institute of Technology	Germany
31483	66	20	66	22	You may mention this Factor five idea here! Again no references here!	Noted. References are included in the sentence before the bullets. We do not expicitly mention the factor 5 idea due to space restrictions	Patrick Jochem	German Aerospace Center (DLR)	Germany
42037	66	23			With regard to change the behaviour of the end-users, curtailment, stimulation and tariffs can be considered as potecial initiatives to steer their behaviour	Noted. Strategies and policy to promote mitigation actions are discussed in 6.7.6.1	Francisco Javier Hurtado Albir	European Patent Office	Germany
31485	66	25	66	26	I would delete this sub-sentence “, or operate appliances such as …” here or move it to the second bullet point above.	Rejected. The second bullet focuses on technology adoption to match energy demand and supply. This bullet focuses on behaviour change, either to reduce overall energy use, or to optimise the use of renewables	Patrick Jochem	German Aerospace Center (DLR)	Germany
2185	66	32	66	32	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	accepted, integrated in the third bullet on adopting energy efficient appliances and systems	Miguel Angel Sanjuán	Technical University of Madrid	Spain
12501	66	32	66	32	Please, add a 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	accepted, integrated in the third bullet on adopting energy efficient appliances and systems	MORA PERIS PEDRO	Profesor Titular de Universidad de la ETSI Minas y Energía de la Universidad Politécnica de Madrid	Spain

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
45377	66	39	67	12	Additionally, motivation to undertake mitigation may be impacted by self-interest related to geographic locationm which impacts concern about climate change, with coastal dwellers more concerned than those living away from the coast: "Proximity to Coast Is Linked to Climate Change Belief" Taciano L. Milfont, Laurel Evans, Chris G. Sibley, Jan Ries, and Andrew Cunningham, 2014, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4105574/	Noted, personal climate risks can indeed be part of a cost benefit consideration. We do not elaborate on this in this section due to space restrictions	Deborah Knuckey	Published energy journalist plus consultant for renewable energy development and finance companies through Kiterocket	United States of America
31487	66	43	66	43	Besides PV you may also include EVs here. There is a bunch of literature here!	Noted, EVs are discussed in Chapter 10	Patrick Jochem	German Aerospace Center (DLR)	Germany
16681	66		68		A point to be discuseed: the demand side mitigation options might be different in heavily populated urban areas, suburbias and rural zones.	Noted, and agreed, the influence of contextual factors (including infrastructure) on the likelihood of different types of behaviour change is discussed on p 66, line 37-45	Jean Louis Bobin	Sorbonne universités Paris	France
45447	67	13	68	3	The section highlights the impact of individual values, and the effect that social and peer groups can have on developing those values. Are there efforts (commercial or governmental) where these insights have been put to use to encourage behavior and value changes?	Noted. Yes, these insights have been put in practice - section 6.7.6.1 discusses effects of strategies and policy targeting these factors	Girija Parthasarathy	Thermo King	United States of America
5697	67	16	68	3	Robert Frank has recently written about putting peer pressure and "contagion" to work to address climate change via (for example) solar adoption (Robert Frank, Putting Peer Pressure to Work, Princeton University Press, 2020).	Noted,strategies to promote mitigation behaviour are discussed in 6.7.6.1, including social influence strategies (p. 121, line 5-12 in the FOD)	Seth Seth Dunn	General Electric	United States of America
18723	67	44	67	45	Balcombe et al. 2013 - reference is not found in reference section	Accepted.	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
45449	67				How about government mandates such as banning energy hogs - these help in deman side mitigation	Noted, strategies to promote mitigation actions are discussed in section 6.7.6.1 en in Chapter 13	Girija Parthasarathy	Thermo King	United States of America
18725	68	10	68	29	This section mentions energy systems - but is focussed on the electrical system - rather than the natural gas or liquid fuels systems. It would be helpful to point this out more clearly. i.e. change the first sentence to: 'Many countries are choosing to initially focus on decarbonisation of their electrical energy systems in order to decarbonise their wider energy systems. Electrcial energy systems are therefore undergoing fundamental transformation in response to tightening energy sector decarbonisation targets.'	This has been clarified in the new paragraph at the beginning	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
8905	68	10	71	35	The whole chapter 6,4,6 presents an energy system based on integration and flexibility, supposedly ideal, cost effective, etc.. You may promote this scheme (I wonder if it's really the rôle of ICC?) but I believe you must introduce some shades or restrictions. So far, this is a theory which has never been enforce in real life. In addition, number of studies tend to demonstrate that this theory is based on unrealistic hypothesis from a technical (stability of the network) and social point of vew. I observe that you acknowlege these limits on page 88, lines 6 to 8.On Page 70, lines 16 to 18, you assert that the total cost of investment is more tha 25% lower. Lower than what? On which reference is this based?	We have introduced the restrictions in this chapter. We modified this sentence as "Analysis demonstrates that flexibility technologies and advanced control of integrated multi-vector energy systems would reduce the total cost of investment in energy generation and network infrastructure in low carbon energy systems for more than 25% compared to the scenario where these flexibility technologies and coordinative control for multi-energy system integration are absent." We have also added the relative reference.	Michel SIMON	Vice Président SFENRAL	France
43691	68	10			There are other important dimensions, notable demand response, that becomes especially notable when increasing load is battery related --> electric cars. But also other demand response measures that are activated by time-varying pricing.	This information is mentioned in the section "Role and value of flexibility technologies and advanced control systems", under the bullet "Demand Side Response (DSR)".	Felix Creutzig	MCC Berlin	Germany
9053	68	11	68	16	The amount of flexibility needed depends on the generation variability of the chosen renewable portfolio. This variability can be substantially reduced from climate-informed siting of generators and optimization of different types of generation. This aspect is so fundamental that it should be included in the first paragraph, in my opinion. One could add this sentence in line 15: “Shakoor et al., 2017). The amount of flexibility needed can be substantially reduced through climate-informed mixes of different renewables (e.g., Heide 2010) and strategic siting (e.g., Grams 2017). There are two...” References: Heide, D. et al. Seasonal optimal mix of wind and solar power in a future, highly renewable Europe. Renewable Energy 35, 2483–2489 (2010). Grams, C. M., Beerli, R., Pfenninger, S., Staffell, I. & Wernli, H. Balancing Europe’s wind-power output through spatial deployment informed by weather regimes. Nature Clim Change 7, 557–562 (2017).	This has been addressed based on the reviewer's suggesion. Key references are included.	Jan Wohland	ETH Zürich	Switzerland
9055	68	17	68	18	“Balancing services” are not completely clear. I understand from context and the remainder of the section that the authors refer to systems reserves and voltage/frequency stability. As the term is also used in the context of (large-scale) transmission, I suggest to specify what is meant here.	We added (e.g. operating reserve and frequency response) to clarify balancing services.	Jan Wohland	ETH Zürich	Switzerland

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
42367	68	17	68	18	The statement “One effect is reduced efficiency of system operation; that is, the need for balancing services will…” is incorrect because it only applies to the condition of low penetration where there is low storage role. There is significant mis-understanding about grid with very high shares of variable renewable energy (VRE). This is partly generated because of wrong modelling techniques to study the subject. To correctly address 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 technology [3]. Up to 90% VRE penetration, the suitable storage technologies are of diurnal type while the need for seasonal storage increases above 90%. (vi) These lessons and all other related issues point to the need for better system level science to reach to better understanding of the future system [1]. In short, the above evidences also show that high VRE grid requires its own set of designing and operational rules that significantly differs from the present grid. Thus, the issues of balancing need should be seen together with this facts. At the same time, discussion of efficiency should also be at system level, not at the level of the conventional technologies that are utilized to balance the system.	This statement considers the integration of high penetration of VRE into the existing power system, which lacks flexibility, it focuses on the cost-effective transition to the low-carbon energy system with various flexibility measures. We acknowledged that a better design of the system can effectively enable a high penetration integration of VRE, but it also requires very significant investments and decommision of the existing infrastructure, which are critical for the strategic planning to facilitate the energy system transition. Regarding the curtailment of VES, we also mentioned rapid cost reduction can potentially make VRE economically competative even with substantial curtailment. Key references are included.	Solomon Asfaw	LUT University	Finland
42367					Comment continued: More importantly, conventional technology level efficiency could also decrease on its own due to the need to integrate CCS/CCU even if we ignore its system role to integrate more VRE. 6.Solomon A.A. Large scale photovoltaics and the future energy system requirement. AIMS Energy, 2019, 7(5):600–618 7. 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 8. Solomon AA, Bogdanov D, Breyer C (2019) Curtailment-storage-penetration nexus in energy transition. Applied Energy 235:1351–1368 9. 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. 10.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 11.Solomon AA, Faiman D, Meron G (2011) Appropriate storage for high-penetration grid-connected photovoltaic plants. Energy Policy 40:335–344. 12. 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.		Solomon Asfaw	LUT University	Finland
9057	68	18	68	20	Nuclear generation can also be curtailed if there isn’t enough flexibility to manage mismatches between generation and load. As you mention both renewables and nuclear in the first half of the sentence, it would only be fair to also mention both in the second half: “leading to curtailment of renewable or nuclear output.”	We have mentioned "nuclear" as suggested by the reivewer	Jan Wohland	ETH Zürich	Switzerland
18619	68	18	68	20	"An absence of flexibility will reduce the ability of the system to accommodate VRE and baseload nuclear generation". First, this is not sourced. Second, this seems to be in contradiction with the claim that nuclear power is dispatchable, and that VRE is the main issue (same chapter, page 40 line 48 to page 41 line 2: Nuclear power plants have the technical potential to provide these services by operating in a flexible manner with minor additional investments (e.g. in France, Germany)"). In short, if nuclear power is dispatchable at a reasonable cost as claimed page 40-41, is accommodating baseload nuclear generation actually as big a concern as it is with accommodating VRE, as claimed page 48? Please clarify.	Firstly, we have added the relative reference. Secondly, regarding nuclear generation, the LCOE of nuclear is based on very high load factor, typically 80%-90%. If nuclear power plants operate in a flexible manner to provide balancing services, its LCOE will significantly increase,which makes it less competative in the low carbon scenario. Basically, curtailment of nuclear is equivalent to curtailment of RES. Therefore, we assume, which is also typical for nuclear generation, that it supplies electricity baseload at very high load factor.	Thomas Gibon	Luxembourg Institute of Science and Technology (LIST)	France
31831	68	20	68	20	Any reason why only nuclear is mentioned as the base load option threatened by variable renewables?	The LCOE of nuclear is based on very high load factor, typically 80%-90%. If nuclear power plants operate in a flexible manner to provide balancing services, its LCOE will significantly increase,which makes it less competative in The low carbon scenario. Therefore, we assume, which is also typical for nuclear generation, that it supplies electricity baseload at very high load factor. The other based load options, e.g. hydro power, are typically flexible in adjusting their output, therefore less threatened by variable RES.	Ashok Sreenivas	Prayas (Energy Group)	India
9059	68	20	68	22	This sentence is worded too strongly, because a certain amount of curtailment can be acceptable and may even be economically optimal. I suggest to replace “would” with “could”.	It has been addressed based on the reviewer's suggestion	Jan Wohland	ETH Zürich	Switzerland

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
39685	68	20	68	22	The claim that curtailment will hinder the energy transition and increase overall cost is not necessarily true. There are studies arguing that decreasing costs will make renewables cost competitive even with substantial curtailment. Some even argue that oversizing of PV systems shoiuld be oversized to reach cost-effective systems. This should at least be acknowledged. See eg. Perez, M., Perez, R., Rábago, K.R., Putnam, M., 2019. Overbuilding & curtailment: The cost-effective enablers of firm PV generation. Solar Energy 180, 412–422. https://doi.org/10.1016/j.solener.2018.12.074	We have acknowledged this important point. Key references are included.	Simon Davidsson Kurland	Chalmers University of Technology	Sweden
18727	68	24	68	24	change 'The other effect is degradation in the utilisation of energy infrastructure …' to 'The other effect is degradation in the utilisation of electrical systems infrastructure …'	We have addressed it based on this suggestion	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
9061	68	24	68	26	I am convinced that the second half of this sentence is either unclear or wrong: “intermittent renewable generation will displace the energy produced by conventional fossil-fuel plants, but its ability to displace the capacity of the conventional plant will be very limited.” Do you refer to the provision of inertia and apparent power? If yes, please make this clearer. And please discuss that other ways to ensure sufficient levels of apparent power exist. If you do not refer to inertia/apparent power, then please specify what exactly you are talking about here.	Due to the intrinsic intermittency,the ability of intermittent renewable to displace the capacity of the conventional plant will be very limited in the absence of sufficient flexibility, since back-up generation has to be online when there is not enough RES and storage. We have made it clearer in the text.	Jan Wohland	ETH Zürich	Switzerland
42369	68	24	68	26	The statement “that is, intermittent renewable generation will displace the energy produced by conventional fossil-fuel plant ,…..” is also incorrect. Renewables and its enabling technologies can effectively displace conventional power plants if we follow new concept on system design and operation. Please see Figure 3 and Figure 4 in [1]. Both figures present a case for Californian and Israeli grid. As VRE penetration increases conventional capacity need significantly decreases. The slow decrease in Israeli grid may be due to slow retiring rate of existing power plants than the limitation on the side of PV plus storage to replace conventional power plants. There is no-doubt that we need to enhance our systemwide thinking but for that to happen the scientific community needs to have a fresh look at the subject with better tools. This is key and its mandatory for effective transition. 1.Solomon A.A. Large scale photovoltaics and the future energy system requirement. AIMS Energy, 2019, 7(5):600–618	Intermittent renewable generation can effectively displace the energy produced by conventional fossil-fuel plants, but it cannot displace the capacity of conventional fossil-fuel plants without enabling flexibility sources. Take the European system as an example, there are evidences indicating that there can be very low level of or even no intermittent RES for weeks. In this case, Intermittent RES without adequate flexibility sources (such as long-duration storage or H2 generation) will not be able displace large capacity of conventional fossil-fuel plants.	Solomon Asfaw	LUT University	Finland
4477	68	24	68	29	Cross-vector coupling, i.e. integrated use of different energy infrastructures and energy carriers, in particular electricity, heat and gas, e.g. conversion of (surplus) renewable electricity to hydrogen or other fuels or use of waste heat for district heating is a way to increase flexibility and decarbonise the energy system (Briefing European Parliament, Energy storage and sector coupling Towards an integrated, decarbonised energy system, http://www.europarl.europa.eu/RegData/etudes/BRIE/2019/637962/EPRS_BRI(2019)637962_EN.pdf.; DIRECTIVE (EU) 2018/2001 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2018 on the promotion of the use of energy from renewable sources (recast), https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32018L2001&from=EN	Cross-vector coupling has been elaborated in the new paragraph at the beginning. Key references are included.	Leonardo Barreto	Austrian Energy Agency	Austria
42013	68	24			This paragraph should address the impact that charging and in general interaction of electric and hybrid vehicles, following their large-scale integration, will have in electric networks. Not only the impact on the operation, but also in the degradation.	We have added "even with large-scale deployment of storage, e.g. EVs, to address the intermittency and variability of RES, constant charging/discharging will inevitably leads to the degradation of batteries, posing great impact on the optimal operation of electricity systems" in the indicated paragraph.	Francisco Javier Hurtado Albir	European Patent Office	Germany
31489	68	26	68	26	After this sentence you may introduce the Load Duration Curve and demonstrate why it is hard to replace all fossil power plants and why RES are decreasing the profitability of fossil power plants.	We have added "The load factor of conventional fossil-fuel plants which can be described by the Load Duration Curve will drop significantly, jeopardizing the generation efficiency, thereby decreasing the profitability of fossil-fuel plants." at the indicated place.	Patrick Jochem	German Aerospace Center (DLR)	Germany

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
9063	68	26	68	28	The electrification of the heating and transport sector can also reduce peak demand if the inherent flexibility in these systems (heat capacity of buildings, usage patterns of electric vehicles) is utilized in a smart way. I therefore suggest to rephrase the following sentence to add this opportunity in addition to the risk that you already mention: “Furthermore, the electrification of segments of the heat and transport sector represents a major challenge as the increase in peak demand may be disproportionally higher than the corresponding increase in energy.” For example: “represents both a challenge and an opportunity as peak demand may increase or decrease dependend on the specific system. Sector-coupling may allow to decrease the ratio of peak to demand to energy consumption if the flexibility in non-electricity sectors is used efficiently. It could, however, also lead to higher peak demand under in non-optimal systems.”	We have added "Meanwhile, it also represents an opportunity to reduce the total system costs in the context of sector-coupling which may allow to decrease the ratio of peak demand to energy consumption if the flexibility in non-electricity sectors is used efficiently, e.g. electric vehicles and heat devices are integrated into the energy system synergistically with an efficient control mechanism." at the indicated place.	Jan Wohland	ETH Zürich	Switzerland
31491	68	28	68	28	Again a reference is missing. You may add after this sentence: “However, if electric vehicles and heat devices are integrated into the energy system synergistically (i.e. with an efficient control mechanism, total system costs decline (Babrowski et al., 2014; Dengiz et al., 2019)” Babrowski, S.; Heinrichs, H.; Jochem, P.; Fichtner, W. (2014): Load shift potential of electric vehicles in Europe: chances and limits, Journal of Power Sources 255, 283-293, doi: 10.1016/j.jpowsour.2014.01.019. Dengiz, T.; Jochem, P.; Fichtner, W. (2019): Demand response with heuristic control strategies for modulating heat pumps, Applied Energy 238, 1346-1360, doi: 10.1016/j.apenergy.2018.12.008	We have added "Meanwhile, it also represents an opportunity to reduce the total system costs in the context of sector-coupling which may allow to decrease the ratio of peak demand to energy consumption if the flexibility in non-electricity sectors is used efficiently, e.g. electric vehicles and heat devices are integrated into the energy system synergistically with an efficient control mechanism." at the indicated place. Key references are included.	Patrick Jochem	German Aerospace Center (DLR)	Germany
6459	68	30	70	18	All flexibility technology options are considered in isolation. Yet, it is very interesting and crucial to also take into account the interdependencies of different options. I think an additional paragraph on the interactions of different flexibility options would be a great addition. Some relevant references include: Haller, M., Ludig, S., Bauer, N., 2012. Bridging the scales: a conceptual model for coordinated expansion of renewable power generation, transmission and storage. Renew. Sust. Energ. Rev. 16 (5), 2687–2695. Neetzow, P., Pechan, A., Eisenack, K., 2018b. Electricity storage and transmission: complements or substitutes? Energy Econ. 76, 367–377. Steinke, F., Wolfrum, P., Hoffmann, C., 2013. Grid vs. storage in a 100 % renewable Europe. Renew. Energy 50, 826–832. Schmid, E., Pechan, A., Mehnert, M., Eisenack, K., 2017. Imagine all these futures: on heterogeneous preferences and mental models in the German energy transition. Energy Res. Soc. Sci. 27, 45–56.	We have added "Due to the interdependencies and similarities, there can be both synergies and conflicts for utilizing these flexibility options, therefore, it will be crucial to optimize the deployment of the potential flexibility technologies with smart coordinative control strategies." at the indicated place. Key references are included.	Paul Neetzow	Humboldt-Universität zu Berlin	Germany
20395	68	33	68	36	cross-border cost reduction has been quantified for Europe to 10% and 26 billion EUR per year by Child et al. (https://www.sciencedirect.com/science/article/pii/S0960148119302319)	We have added this information. Key references are included.	Christian Breyer	LUT University	Finland
18729	68	45	68	45	This constitutes a paradigm shift from …' change to 'This constitutes a significant shift from …'	We have made changes based on this suggestion	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
9065	69	3	69	4	I suggest to remove “cross-boarder” and just write “interconnection” or “transmission” instead. The reason is that there are also bottlenecks within countries which currently create additional costs (through congestion management) and might slow down the expansion of renewables. We did a study on Germany in this regard, for illustration (see below). Reference: Wohland, J., Reyers, M., Märker, C. & Witthaut, D. Natural wind variability triggered drop in German redispatch volume and costs from 2015 to 2016. PLoS ONE 13, e0190707 (2018).	We have removed "cross-boarder". Key references are included.	Jan Wohland	ETH Zürich	Switzerland
27945	69	3	69	4	For cross-border interconnections, Archer, C.L., and M.Z. Jacobson, Supplying baseload power and reducing transmission requirements by interconnecting wind farms, J. Applied Meteorol. and Climatology, 46, 1701-1717, doi:10.1175/2007JAMC1538.1, 2007 found that interconnecting wind farms at 19 locations converted completely intermittent power into power that was just as reliable as a coal plant for 33-48% of the year. It also reduiced transmission requirements with little loss in power.	We have added "It also has the potential to improve the reliability of intermittent RES through diversified locating of wind farms and reduce transmission requirements with little power loss." Key references are included.	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
39193	69	18	69	21	There are many, many more references on cross-sectoral approaches, see e.g. very early ones from the 1970s DOI: 10.1126/science.189.4199.255, https://doi.org/10.1016/0038-092X(78)90124-X, Aalborg work on Smart Energy Systems https://doi.org/10.1016/j.energy.2008.04.003 https://doi.org/10.1016/j.apenergy.2015.01.075 http://dx.doi.org/10.1016/j.energy.2017.05.123, https://doi.org/10.1016/j.rser.2016.02.025 and others http://dx.doi.org/10.1002/we.224 https://doi.org/10.1016/j.rser.2013.09.012 https://doi.org/10.1016/j.energy.2018.06.222	Key references are included.	Tom Brown	Karlsruhe Institute of Technology	Germany
45065	69	18	69	21	The “integrated cross-sector energy system operation” is a very important concept that has strengthened since AR5 also in support of the “energy systems” emphasis of the present chapter. Additional content would be highly beneficial.	We have added addition content in the new paragraph at the beginning.	Siir Kilkis	The Scientific and Technological Research Council of Turkey	Turkey
45157	69	18	69	21	The “integrated cross-sector energy system operation” is a very important concept that has strengthened since AR5 also in support of the “energy systems” emphasis of the present chapter. Additional content would be appropriate with additional references from the scientific literature.	Additional references are included.	Siir Kilkis	The Scientific and Technological Research Council of Turkey	Turkey
31493	69	21	69	21	You may also integrate the reference Babrowski et al. 2014 again as this gives an projection of the load shift potential of electric vehicles in Europe. Babrowski, S.; Heinrichs, H.; Jochem, P.; Fichtner, W. (2014): Load shift potential of electric vehicles in Europe: chances and limits, Journal of Power Sources 255, 283-293, doi: 10.1016/j.jpowsour.2014.01.019.	This reference is included.	Patrick Jochem	German Aerospace Center (DLR)	Germany
42015	69	21			The proposal made concerning smart grids for section 6.4.4.4. could also come here, instead	The beneftis of interconnection has already been mentioned in page 69 line 3 (before revision).	Francisco Javier Hurtado Albir	European Patent Office	Germany
31495	69	27	69	27	You may integrate here “increase grid workload,” before “and reduces the need …”	We have added "increase grid workload" at the indicated place.	Patrick Jochem	German Aerospace Center (DLR)	Germany
9067	69	31	69	31	“Low carbon capacity” is a bit difficult to understand here because what you really seem to mean is dispatchable capacity (which could be fossil based but doesn’t have to). I suggest to reword.	We have changed it to "dispatchable low-carbon capacity (e.g. nuclear and fossil-fuel plants with CCS)".	Jan Wohland	ETH Zürich	Switzerland
9069	69	35	69	36	The following sentence leaves open which emission targets are meant and which benchmark scenario is being used (14/20GW less compared to what?). This needs clarification. “For example, this analysis demonstrates that in the UK case, the carbon targets could be met by building 14 GW less nuclear or 20GW less offshore wind generation (Sanders et al. 2016).“	We have reworded this sentence as "For example, this analysis demonstrates that in the UK case, the carbon targets of 80% reduction compared to 1990 level could be met by building 14 GW less nuclear or 20GW less offshore wind generation if sufficient flexibility sources, including storage, DSR and interconnection, are available (Sanders et al. 2016)." The relative references are included.	Jan Wohland	ETH Zürich	Switzerland
45451	69	40	69	44	It is not clear what the 'network' is in this context: the electric grid? Or any energy distribution network ?	We have added "electricity" at the indicated place to make it clearer	Girija Parthasarathy	Thermo King	United States of America
42017	70	7			In the framework of this section, and with regard to advanced control systems, it should be noted that the large-scale integration of EV and HEV will have, in addition to the impact on the electrical power tranmission infraestructure, will also impact telecommunications and pull technological development. The data traffic necessary for the interoperablity of the electricity-based vehicles will need appropriate support of the telecommunication networks (which will se how traffic increases), and dedicated technological developments to support such interaction (standardisation, cybersecurity …).	We have added "It is worth noticing that multi-energy system integration highly relies on telecommunication and monitoring infrastructure, which will incur extra environmental, economical, energetical costs. Since supercomputers need quite a lot of energy, national or continent-wide integrated energy system will require a massive amount of computing power to process the data. In this regard, the data traffic necessary for the interoperablity of the multi-energy system will need advanced ICT networks and dedicated technological developments to support such interaction, which may bring issues of standardization and cybersecurity." in the new paragraph at the beginning.	Francisco Javier Hurtado Albir	European Patent Office	Germany
6457	70	8	70	8	Figure 6.27	This has been clarified	Paul Neetzow	Humboldt-Universität zu Berlin	Germany
9071	70	8	70	10	I would suggest to write “climate change mitigation” instead of “climate change” because the current version could be misunderstood to mean that climate change itself forces us to shift from the old to the new system (e.g., because thermal power plants can no longer be operated under the new climatic conditions).	Agreed, but the focus is on "cost effective transition to low carbon energy system"	Jan Wohland	ETH Zürich	Switzerland
28895	70	8	70	10	Figure 6.27. source?	We have added the source of this figure.	Marissa Malahayati	National Institute for Environmental Studies	Japan

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
24343	70	11	70	18	No mention of the costs (environmental, economical, energetical) of grid monitoring. How can we operate it ? Numerical monitoring is very energy-dependent. Supercomputers need quite a lot of energy and we do not know the computing power that one needs to monitor such a system. As we regularly say that the grid needs to be almost continent-wide, it will require a massive amount of computing power to monitor those data.	We have added "It is worth noticing that multi-energy system integration highly relies on telecommunication and monitoring infrastructure, which will incur extra environmental, economical, energetical costs. Since supercomputers need quite a lot of energy, national or continent-wide integrated energy system will require a massive amount of computing power to process the data. In this regard, the data traffic necessary for the interoperablity of the multi-energy system will need advanced ICT networks and dedicated technological developments to support such interaction, which may bring issues of standardization and cybersecurity." in the new paragraph at the beginning.	Alan BURLOT	Commissariat à l'énergie atomique et aux énergies alternatives	France
31497	70	18	70	18	I'm missing a reference here.	We have added the relative reference.	Patrick Jochem	German Aerospace Center (DLR)	Germany
13857	70	19	70	19	Cost assessment would merit a deeper analysis beyond LCOE and one study building the "Whole System Cost". Limits of system LCOE at high VRE share are not clearly stated. Namely "system LCOE" is an interesting metric that literature explored and even agreed on the orders of magnitudes of the different range of costs forecasted. Criticising LCOE might be relevant to guide policy decision.(1) F. Ueckerdt, L. Hirth, G. Luderer, and O. Edenhofer, "System LCOE: What are the costs of variable renewables?," Energy, vol. 63, pp. 61-75, 2013, doi: https://doi.org/10.1016/j.energy.2013.10.072. (2) A. S. Brouwer, M. van den Broek, W. Zappa, W. C. Turkenburg, and A. Faaij, "Least-cost options for integrating intermittent renewables in low-carbon power systems," Applied Energy, vol. 161, pp. 48-74, 2016, doi: https://doi.org/10.1016/j.apenergy.2015.09.090. (3) L. Hirth, F. Ueckerdt, and O. Edenhofer, "Integration costs revisited – An economic framework for wind and solar variability," Renewable Energy, vol. 74, pp. 925-939, 2015, doi: https://doi.org/10.1016/j.renene.2014.08.065. ¨	We have added "Due to various system requirements for the integration of RES, LCOE cannot reflect the realistic cost of RES at high penetration. Therefore, System Integration Costs (SIC) is introduced to complement LCOE to represent the additional costs incurred to integrate RES." at the indicated place. Key references are included.	Alexandre Bizeul	International Energy Agency	France
17063	70	19	71	35	A very important reference is missing here: Brown et al. 2018 Synergies of sector coupling and transmission extension in a cost-optimised, highly renewable European energy system. This is probably the one paper that carries out optimization across all flexibility options (grid expansion, demand response, short- and long-term storage).	We have added "Due to the interdependencies and similarities, there can be both synergies and conflicts for utilizing these flexibility options, therefore, it will be crucial to optimize the deployment of the potential flexibility technologies with smart coordinative control strategies". Key references are included.	Kornelis Blok	Delft University of Technology	Netherlands
17065	70	19	71	35	Also, the work of Breyer et al should be discussed here. Summary report here: http://energywatchgroup.org/wp-content/uploads/EWG_LUT_100RE_All_Sectors_Global_Report_2019.pdf. Abundant references, for many countries, in Appendix.	We have added "Furthermore, global interconnection increases the reliability of the electricity system in comparison to the national interconnected network, and reduces the required capacity to meet demand." Key references are included.	Kornelis Blok	Delft University of Technology	Netherlands
28449	70	19	71	35	something ought to be said for the predictability of tidal energy in this section, althoguh it may not have been included due to such small market share, but preditability of tides useful in a future grid and the quality of electricity is also hgiher than other non-renewable forms of energy (altough the article appears to then talk about LCOE beign a bad measure) : Lewis, M., McNaughton, J., Márquez-Dominguez, C., Todeschini, G., Togneri, M., Masters, I., Allmark, M., Stallard, T., Neill, S., Goward-Brown, A. and Robins, P., 2019. Power variability of tidal-stream energy and implications for electricity supply. Energy, 183, pp.1061-1074.	We have metioned the predictability of tidal energy at the indicated place. Key references are included.	Matt Lewis	Bangor 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
42371	70	19	71	35	The message in section 6.4.6.2 needs correction. First, the future energy system needs a fundamentally different system composition, which is clearly noted in [1-4]. This is what Figure 6.28 also suggests, even taking with its existing flaws. Second, appropriate methodology and interpretation also matters. A significant misunderstanding of the physics of future energy system, without which no convincing evaluation can be achieved, are notable in most such studies (if you look at basic requirement of suitable economic models discussed in [1-3]). Evaluation techniques such as this one are more relevant to understand the near future challenges, may be for penetration as high as 30% VRE. The cost that constituted integration cost are developed based on the present day challenge and system composition. As penetration goes up the system must evolve. Thus, your statement on line 17-20 of page 70 lacks proper justification. For example, the supply shortage/security becomes an issue on some seasons if you go to more than 90% VRE penetration when the system is not properly designed. At lesser VRE penetration, storage, VRE and conventional generators could be properly operated without risk of supply security [1-3]. The supply shortage at peak load hour may be system design and location specific because data's refuting that already exist. Please see [1]. Not only it refutes this assertion, but it also indicates that peak load based reserve planning seize to work. Third, technology cost is changing significantly from year to year. It is better to avoid making statements such as the one on page 71 line 20 in addition to correcting the over all message. Because in other studies an affordable high renewable energy system is consistently reported (though caution is still necessary due to high uncertainty about the future both technically and economically). It is not mandatory to keep significant firm capacity generators of what ever kind to reach to high penetration, unless those are local policy choice enforced for some reason. But it is always preferable to rely on diverse resource if it is possible. 1.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. 2.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. 3.Solomon AA, Bogdanov D, Breyer C (2019) Curtailment-storage-penetration nexus in energy transition. Applied Energy 235:1351–1368 4.Solomon A.A. Large scale photovoltaics and the future energy system requirement. AIMS Energy, 2019,	We have made modification for section 6.4.6.2 the key references are included.	Solomon Asfaw	LUT University	Finland
46091	70	19	71	35	And power-to-heat? That is much cheaper than power-to-gas, but it is not mentioned. Only LTES is mentioned, but not in explicit context of P2H, and we know that thermal LTES is more compatible with direct use of solar thermal energy than excess VRES, while for integration of VRES short term heat storage is more feasible.	We have added the example of power to heat by inserting "excess RES-based power can also be converted to thermal energy (Power-to-Heat), e.g. in summer, and released when heat demand is high through LTES." Since VRES can be seasonally disproportional to the demand, LTES (seasonal) will improve the its utilisation. We have emphasized this point in the same paragraph.	Neven Duic	University of Zagreb	Croatia
37873	70	19			There is a substantial strand of literature about the renewable energy integration costs (e.g., Hirth, Lion. „The market value of variable renewables: The effect of solar wind power variability on their relative price". Energy Economics 38 (Juli 2013): 218–36. https://doi.org/10.1016/j.eneco.2013.02.004. Milligan, M., Kirby, B., 2009. Calculating wind integration costs: separating wind energy value from integration cost impacts. NREL Technical Report TP-550-46275. Milligan, M., Ela, E., Hodge, B.M., Kirby, B., Lew, D., Clark, C., DeCesaro, J., Lynn, K., 2011. Integration of variable generation, cost-causation, and integration costs. Electr. J. 24 (9), 51–63. Ueckerdt, Falko, Lion Hirth, Gunnar Luderer, und Ottmar Edenhofer. „System LCOE: What are the costs of variable renewables?" Energy 63, Nr. Supplement C (15. Dezember 2013): 61–75. https://doi.org/10.1016/j.energy.2013.10.072. Edenhofer, Ottmar, Lion Hirth, Brigitte Knopf, Michael Pahle, Steffen Schlömer, Eva Schmid, und Falko Ueckerdt. „On the Economics of Renewable Energy Sources". Energy Economics 40 (Dezember 2013): S12–23. https://doi.org/10.1016/j.eneco.2013.09.015.)	Key references are included.	Gunnar Luderer	Potsdam Instittute for Climate Impact Research	Germany
31499	70	20	126	32	Please replace "variable" by "fluctuating" or "intermittent" throughout the text! Wind and PV are not VARIABLE energy sources!	Thanks for this suggestion, but we think regarding this issue, there are still controversies. We mentioned at the beginning that RES refers to variable and intermittent renewable energy sources.	Patrick Jochem	German Aerospace Center (DLR)	Germany
45457	71	3			What are some examples of flexibility technologies? (other than advanced control systems mentioned)	As introduced in 6.4.6.1, flexibility technologies include: flexible generation, interconnection, DSR, storage and cross-sector integration	Girija Parthasarathy	Thermo King	United States of America

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
36517	71	8	71	11	Implication of Figure 6.28 is very important but how to get the cost curve or what are assumptions are not explained here. It is better to add explanation of the number of this figure.	We have added the explanation as below "It should be stressed that the results demonstrated in Fig. 6.28 is based on the GB system with a set of assumptions regarding the inflexible and flexible systems, i.e. we assume that flexible generation, interconnection, DSR, electrical storage and cross-sector integration are present in the flexible systems while none of the these flexibility measures are available in the inflexible system."	Takashi Hongo	Mitsui & Co. Global Strategic Studies Institute	Japan
9073	71	9	71	11	While this figure is interesting, its caption should clearly state that it is not applicable everywhere. It has to be clear that this is a case study for one very specific domain in the northern hemisphere mid-latitudes and (probably) also for one set of assumptions regarding the location of capacity! Co-variability of solar generation and demand is different in other locations.	We have clarify this figure by adding "It should be stressed that the results demonstrated in Fig. 6.28 is based on the GB system with a set of assumptions regarding the inflexible and flexible systems, i.e. we assume that flexible generation, interconnection, DSR, electrical storage and cross-sector integration are present in the flexible systems while none of the these flexibility measures are available in the inflexible system. Larger scale system (e.g. EU-wide) would drive lower SIC, due to the increased diversity of RES through strategic locating."	Jan Wohland	ETH Zürich	Switzerland
34397	71	12	71	15	There is a misconception here. CCS and CCU are not sources of energy as is nuclear power, so is should be given as example here. And again, CCS and CCU would not have at all the same effect on the renewable energy system, so it is absolutely wrong to use CCUS in that context. CCS is a relatively old concept that has been proposed at first as a way to reduce the climate impact of continued fossil power generation at increased energy costs (Metz et al., 2005, IPCC-SR-1.5, 2018), but this strategy counteracts the deployment of renewables and shift the environmental costs of today's emissions onto future generations. Hence, large-scale CCS deployment does not represent a step towards a shift of the energy system away from fossil resources (e.g. ZERO, 2015, Bruhn et al., 2016). Current trends worldwide indicate that energy systems in this century will increasingly be based on electricity, mainly due to high technical efficiencies, comparably lower costs and the availability of prospective power-to-X technologies. These power-to-X technologies include sustainable or nonavoidable CCU (Farfan et al., 2019, Ram et al., 2019). Excess renewable energy, generated when the demands for energy are low, could potentially provide an inexpensive or even negatively priced energy supply for CO2 conversion to products. Energy storage technologies could harness excess generation that would otherwise be curtailed and make it available for use in CCU. Transport technologies are also expected to play an important role due to the likelihood that conversion technologies and sources of raw material will be in different locations (Jarvis and Samsatli, 2018). (ZERO, 2015, Putting It Back—A Series on Storage of CO2 (part 3)—Global NGO Views on CCS and Storage of CO2. Zero Emission Resource Organisation./ Jarvis and Samsatli, 2018, Sustain.Energy.Rev, 85, 46-48/Farfan et al., 2019, J. Clean Prod., 217, 821-835./ Bruhn et al., 2016, Environmental Science & Policy, 60, 38–43./ Metz et al., 2005, IPCC Special Report on Carbon Dioxide Capture and Storage. Cambridge University Press, New York/ Ram et al., 2019 EWG&LUT, 2019: Global Energy System Based On 100% Renewable Energy, Energy Watch Group & LUT University./IPCC Special Report 1,5degC, 2018: Special Report 1.5 – Summary for Policy Makers, Intergovernmental Panel on Climate Change (IPCC)).	We have replaced CCSU by "thermal plants with CCS"	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
5215	71	12	71	20	Only use one currency over the entire publication.	We have used $ as the currency	Andreas Oberheitmann	FOM University of Applied Sciences	Germany
20521	71	12	71	20	research results show that well designed energy systems have access to enough flexibility for low cost, as shown by Bogdanov et al. (https://www.nature.com/articles/s41467-019-08855-1 ; https://www.sciencedirect.com/science/article/pii/S0306261919312802), Ram et al. (http://energywatchgroup.org/wp-content/uploads/EWG_LUT_100RE_All_Sectors_Global_Report_2019.pdf) and Brown et al. (https://www.sciencedirect.com/science/article/pii/S036054421831288X). All studies are in full hourly resolution for describing flexibility best.	We have mentioned this point by adding "system flexibility driven by advanced technologies and appropriate system design" at the indicated place. Key references are included.	Christian Breyer	LUT University	Finland
36347	71	13			Please use US$ instead of £	It has been addressed based on the reviewer's suggestion	Youba Sokona	South Centre	Switzerland
9075	71	17	71	21	This sentence is not clear enough. I assume that it refers to wind and solar not being able to provide sufficient supply. Depending on the precise context, other renewable types of generation could step in (such as hydropower or biomass).	We have changed it to "intermittent RES (e.g. wind and solar) cannot provide" to make it clearer.	Jan Wohland	ETH Zürich	Switzerland
36349	71	17			Please use US$ instead of £	It has been addressed based on the reviewer's suggestion	Youba Sokona	South Centre	Switzerland

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
31833	71	21	71	21	The previous para states that, if the system is flexible, integration costs of variable renewables will not be high. So this sentence is contradictory to that.	We have changed this sentence to "Going towards zero carbon energy system, intermittent RES has to be supported by appropriate amount of firm capacity of low-carbon generation (e.g. biomass, biogas, etc.) and energy storage to guarantee supply security and system stability." to make it clearer.	Ashok Sreenivas	Prayas (Energy Group)	India
9077	71	21	71	22	I don't think that nuclear is a particularly good example here unless there is evidence that nuclear can be ramped sufficiently quick and often to serve this task. I would suggest to replace the nuclear example with, for example, biogas as gas turbines are known to fulfil these criteria.	We have changed nuclear to biogas, biomass, etc. Clarification: The size of nuclear can be optimized to efficiently supply the base-load, thus reducing the penetration of RES to fulfill the zero-carbon target. Although other types of flexible low-carbon generation such as biogas are also required to provide ancillary services and back-up capacities.	Jan Wohland	ETH Zürich	Switzerland
37405	71	21	71	22	the statement that "firm low carbon generation e.g. nuclear will be required" is highly misleading, as also biomass and variable renewably energy and storage provide firm generation.	We have modified this sentence by "Going towards zero carbon energy system, intermittent RES has to be supported by appropriate amount of firm capacity of low-carbon generation (e.g. biomass, biogas, etc.) and energy storage to guarantee supply security and system stability."	Michiel Schaeffer	Climate Analytics	Netherlands
39195	71	21	71	22	The statement "Going towards zero carbon energy system, integration costs of renewables could increase significantly, indicating that significant capacity of firm low carbon generation (e.g. nuclear) will be required." is not well supported by the literature, see the many papers on 100% renewable energy systems cited in Brown et al https://doi.org/10.1016/j.energy.2019.03.092 and https://doi.org/10.1016/j.energy.2019.03.092	We have modified this sentence by "Going towards zero carbon energy system, intermittent RES has to be supported by appropriate amount of firm capacity of low-carbon generation (e.g. biomass, biogas, etc.) and energy storage to guarantee supply security and system stability." We also mentioned "System flexibility driven by advanced technologies and appropriate system design (Bogdanov, Farfan et al. 2019, Solomon, Bogdanov et al. 2019)(Bogdanov et al.) reduces system integration cost of renewable generation very significantly (as penetration level increases), which considerably enhances the competitiveness of renewable generation." Additionally, we mentioned that H2 can enable a 100% RES scenario with the support of electrolysers, H2 storage and H2 based power plants (e.g. CCGT). Although it is currently not economically competative, but it can provide an solution with the rapid development and cost reduction of various technologies. Key references are included.	Tom Brown	Karlsruhe Institute of Technology	Germany
45453	71	21	71	35	What is the technology readiness level of the art for LTES? Is is at prototype demonstations, or are there commercial installations? What is the efficiency of electrolysers? One would assume there is value in using the current thermal generation plants for renewable produced hydrogen or ammonia driven thermal generation.	We have added "(currently at different stage of commercialisation)" to make it clearer. We also added "although the low efficiency of energy conversion (e.g. Power-to-Gas) can bring the round-trip efficiency of such storage down" to clarify	Girija Parthasarathy	Thermo King	United States of America
18731	71	27	68	29	The benefit and value of LTES technologies in enabling the use of more variable and lower cost RES instead of higher-cost but firm low-carbon generation such as nuclear or CCUS has also been ' this sentence does not seem to be finished	We have finished this sentence by adding "assessed in previous work".	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
6389	71	27	71	27	Phase change materials (latent heat thermal energy storage) is suitable for short duration storage, from a few hours to max intraday. It is suggested to remove 'phase change materials' from the options of long term energy storage	We have removed "phase change materials"	Sciacovelli Adriano	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
6043	71	27	71	29	Hanging sentence 'The benefit and value of LTES technologies in enabling the use of more variable and lower cost RES instead of higher-cost but firm low-carbon generation such as nuclear or CCUS has also been ….'	We have finished this sentence by adding "assessed in previous work" at the end	SAIK PENG, CASEY NGO	R-SYNC TECHNICAL RESOURCES SDN. BHD.	Malaysia

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
34399	71	27	71	31	Same comment as above (for line 12-15), there is a misconception. CCUS does not allow to create energy. When it comes to power to gas, the term CCU should be used as it is CCU (and not CCS) that as the power to stimulate the energy transition by enabling energy storage through power-to-X approaches and contribute to a circular economy by converting waste emissions into resources (IEAGHG, 2019b, Castillo-Castillo, 2019, Zhu, 2019, CCES, 2019).(IEAGHG, 2019b: Exploring Clean Energy Pathways: the role of energy storage, International Energy Agency./Zhu, 2019, Clean Energy, Vol. 3, No. 2, 85–100./Castillo-Castillo, 2019, Policy analysis and recommendations for EU CO2 utilisation policies. In: CEST2017 15th International Conference on Environmental Science and Technology, Rhodes, Greece.)	We have changed "CCUS" to "thermal plants equipped with CCS"	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
9079	71	29	71	29	There is a word missing. Has also been WHAT?	We have finished this sentence by adding "assessed in previous work" at the end	Jan Wohland	ETH Zürich	Switzerland
38017	71	32	71	33	This sentence is misleading: “Energy in the form of hydrogen/ammonia can be stored across long time horizons as losses are minor and not time-dependent”. It is correct that there are low (evaporation) losses in the storage tanks. But there are very high losses in the storage cycle, which is not mentioned at all. So the reader can misunderstand, and believe that hydrogen/ammonia storage is almost lossless. Suggestion: Write a sentence about the round-trip efficiency of storage	We have added "although the low efficiency of energy conversion (e.g. Power-to-Gas) can bring the round-trip efficiency of such storage down" to clarify.	Atle Harby	SINTEF Energy Research	Norway
39293	72	1	73	10	under construction, but in present form I do not see that the storage mean and cost as well. Price on production only is not the most relevant, a kwh of dispatchable energy source is more valuable than a kwh of dispatchable energy, despite the latter having a lower production cost, or is it that the storage is taken into account already but not showed ? (but then the values seem a bit off)	We only consider the LCOE for power generation technologies at this moment. We will think about how to include the storage cost.	Bruno Gavazzi	UMR7516 Institut de Physique du Globe de Strasbourg (CNRS/Université de Strasbourg	France
45459	72	1	73	10	Looking forward to completed section 6.4.7 with the sumary tables	Noted, thanks.	Girija Parthasarathy	Thermo King	United States of America
15529	72	2	72	13	I encourage the others here to not take too narrow a view of what constitutes a mitigation option. Mitigation options need not only be technologies and practices that seek to directly displace fossil fuel demand, but could also include supply. See e.g. Lazarus, M. & van Asselt, H. Fossil fuel supply and climate policy: exploring the road less taken. Climatic Change 150, 1–13 (2018). Green, F. & Denniss, R. Cutting with both arms of the scissors: the economic and political case for restrictive supply-side climate policies. Climatic Change 150, 73–87 (2018)	Noted, we do assess supply and demand options	Peter Erickson	Stockholm Environment Institute	United States of America
37033	72	3	72	13	How can feasibility and desirablity be alternatively used? Conceptually very clearly in mathematical programming a Feasible set can be a subset of desirable set if constraints/ barriers are considered. So interchangebaility of these two terms are scientifically odd. Needs careful ocsideration.	accepted, we now consistently refer to feasibility.	Joyashree Roy	Asian Institute of Technology, Thailand. Jadavpur University, India	Thailand
39333	72	4	72	4	In this context it is worth while to mention that the levelised cost should be outlined with and without battery storage, because none of the VRE generator can be depended upon without proper storage facilities from the grid context	We only consider the LCOE for power generation technologies at this moment. We will think about how to include the storage cost.	Suvra Majumdar	United Nations Development Programme	India
42687	72	7	72	12	Table 6.15 is not clear, may be reworked.	Noted. The Table is a placeholder, so work in progress	ABHA CHHABRA	Space Applications Centre, Indian Space Research Organisation	India
19895	72	7	72	13	While Table 6.15 is under construction, it should be neutral and well-balanced ones. Table 4.11 of SR15 does not address reliability or geopolitical supply security. VRE has weakness in terms of "reliability." Solar and battery has weakness in terms of geopolitical supply security due to uneven geological distribution of rare earth elements or metals. Table 4.11 without due regard to these elements gives an impression that wind and solar is almost perfect option in every aspects, which is not true.	Noted. We will assess the role of context when assessing the barriers and enablers of feasibility of differn options. The assessment will be based on the scientific literature, so will be well-balanced. Geopolitical issues are addressed in the assessment of the institutional feasibility	Takahiko Tagami	Institute of Energy Economics, Japan	Japan
1227	72	11			Mention details about Ec, Tec, Inst, Soc, Env, Geo. Mention what does it mean by evidence, agreement and context? Without defining the terms, the table is not understandable.	Noted. The terms are introduced in Chapter 1, and explained in Section 6.4.1. The assessment method will be further explained indeed, when the table is completed	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
2349	72	12	72	12	Table is not fully visible	Noted. The Table is a placeholder, it is work in progress	Dieter Boer	Universitat Rovira i Virgili	Spain
3011	72				Table 6.15: The economic dimension of feasibility should assess the full cost of the technology rather than the generation or simply the levelized cost. Accounting for intermitancy and infrastructure requirements may affect the ranking in the table. Also whether the "Env" column uses LCA?	Noted, the assessment of economic feasibility will be based on investment costs (investments per ton CO2 avoided), costs in USD/tCO2-eq, and when relevant hidden costs that may inhibit feasibility	Mustafa Babiker	Aramco	Saudi Arabia
31835	73	1	73	1	It would be good to add a few storage technologies also to this table as they will be increasingly important in the future	We only consider the LCOE for power generation technologies at this moment. We will think about how to include the storage cost.	Ashok Sreenivas	Prayas (Energy Group)	India
20397	73	1	73	5	it is obvious that the LCOE of PV in the projection is wrong, given the fact, that the least cost PV tender TODAY ist at 15.7 USD/MWh: https://www.pv-magazine.com/2020/01/23/qatars-800-mw-pv-tender-saw-world-record-final-price-0-01567-kwh/ ; Vartiainen et al. (https://onlinelibrary.wiley.com/doi/full/10.1002/pip.3189) may be also of help for solar PV in this table	Data updated	Christian Breyer	LUT University	Finland

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
38019	73	1	73	5	LCOE for thermal generation is heavily dependent on the assumed Capacity Factor, which must be clearly stated. Also, it is very important to make it clear if the LCOE of fossil thermal plants includes a CO2-price (or tax) or not. If so: What is the CO2-price assumed. LCOE for CCGT with CCS is listed as 65-69 $/MWh for 2019. That is not a realistic number, since no such plants (except demo/pilots) exist today. The cost of CCS is highly uncertain, but in the table, CCS have the lowest cost spread. That cannot be correct. Same goes for Coal with CCS: How can coal without CCS in 2019 be more expensive and more uncertain than Coal with CCS?	Accepted. The LCOE of technology varies form country to country. Key inputs to calculating LCOE include capital costs, fuel costs, fixed and variable operations and maintenance (O&M) costs, financing costs, and an assumed utilization rate for each plant type. The cost of CCS is from EIA_Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2019.	Atle Harby	SINTEF Energy Research	Norway
46093	73	1	73	5	PV cost are quite outdated in IAMs, therefore many major conclusions are strongly negatively affected. See Krey et al. (https://www.sciencedirect.com/science/article/pii/S0360544218325039) summarizing the PV cost in all relevant IAMs and then Vartiainen et al. (https://onlinelibrary.wiley.com/doi/full/10.1002/pip.3189), this leads to a factor 4 difference in PV cost in 2050 (or more) – and we are talking on the most relevant energy supply technology globally	Data updated	Neven Duic	University of Zagreb	Croatia
38019	73	1	73	5	LCOE for thermal generation is heavily dependent on the assumed Capacity Factor, which must be clearly stated. Also, it is very important to make it clear if the LCOE of fossil thermal plants includes a CO2-price (or tax) or not. If so: What is the CO2-price assumed. LCOE for CCGT with CCS is listed as 65-69 $/MWh for 2019. That is not a realistic number, since no such plants (except demo/pilots) exist today. The cost of CCS is highly uncertain, but in the table, CCS have the lowest cost spread. That cannot be correct. Same goes for Coal with CCS: How can coal without CCS in 2019 be more expensive and more uncertain than Coal with CCS?	Accepted. The LCOE of technology varies form country to country. Key inputs to calculating LCOE include capital costs, fuel costs, fixed and variable operations and maintenance (O&M) costs, financing costs, and an assumed utilization rate for each plant type. The cost of CCS is from EIA_Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2019.	Atle Harby	SINTEF Energy Research	Norway
20621	73	1	73	9	A forthcoming paper, part of the EMF-33 IAM comparison concerning biomass and bioenergy use in climate change mitigation strategies (reference below), outlines the techno-economic parameterization of bioenergy technologies in IAMs, and its importance in climate change mitigation strategies, can add further data-points in table 6.8. An inclusion of IAM projections concerning costs (or comparison) may be interesting given thier importance in climate change mitigation strategies. The paper also breaks down levelised costs between (i) Capital and O&M, (ii) Feedstock, (iii) CDR costs/benefits from pricing carbon. Interestingly, the levelised costs in this paper largely match those in table 6.4 with the following additional insights: - IAMs show a larger range in the cost of bio-based electricity, with most models agreeing with the range presented in table 6.4. However in some cases IAMs can have significantly higher costs. - IAMs show an increase in levelized costs between 2030 and 2050, largely because of increasing feedstock costs (but of course this is scenario specific - low biomass demand scenarios show lower biomass costs). - Cost of Biomass+CCS decreases in IAMs due to the credit they get are assumed to get when GHG emissions are priced. - While the manuscript focuses on biomass and bioenergy, in the supple,entary material IAM results for all electricity production option (fossil+renewable) are included. DAIOGLOU, V., ROSE, S., BAUER, N., KITOUS, A., MURATORI, M., SANO, F., FUJIMORI, S., GIDDEN, M., KATO, E., KERAMIDAS, K., KLEIN, D., LEBLANC, F., TSUTSUI, J., WISE, M. & VAN VUUREN, D. in review. Bioenergy technologies and climate change mitigation pathways: Results from the EMF33 study. Climatic Change.	Accepted. The cost of bioenergy can be added.	Vassilis Daioglou	Copernicus Institute of Sustainable Development	Netherlands
36519	73	1	73	9	Supply of biomass feed stock is limited so cost of feed stock seems to be increased when more demand is appeared. However, cost in 2050 is lower than present cost. Is the contribution of technology development big enough to offset the increase of cots of feed stock supply?	That's a good comment. We didn't consider the supply of biomass.	Takashi Hongo	Mitsui & Co. Global Strategic Studies Institute	Japan
42967	73	1	73	9	I understand that “Table 6.8 Summary of cost and performance characteristics of key energy technologies” is just a quick sample of some of the levelized cost information you have gathered to date and it will be revised and updated for SOD-Draft. So I suggest to read and include also consideration and data analyzed in the recent reports prepared by the EIA: “Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2020” [February 2020; available at <https://www.eia.gov/outlooks/aeo/pdf/electricity_generation.pdf >] and by Hydrogen Council: “Path to Hydrogen Competitiveness: A Cost Perspective” [January 2020; available at <https://hydrogencouncil.com/wp-content/uploads/2020/01/Path-to-Hydrogen-Competitiveness_Full-Study-1.pdf >].	Accepted. We have updated the report.	MARIO VALENTINO ROMERI	Independent consultant	Italy

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
42969	73	1	73	9	In recent years I published different papers were 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. This solution, if rapidly adopted at scale level, seems to be able to give a contribution to the climate emergency challenge. However, this low-carbon solution has still not been considered in international energy and climate change debate. I suggest to consider the possibility to insert the 'H2FCPowertrain as power generation plant' in "Table 6.8 Summary of cost and performance characteristics of key energy technologies". References: 2015 – M.V. Romeri "Hydrogen and Fuel Cell: A Cinderella or a Disruptive Low-Carbon Solution?" at "2015 Fuel Cell Seminar & Energy Exposition", Los Angeles CA, USA. Available at ECST: <http://ecst.ecsdl.org/content/71/1/227> or <http://dx.doi.org/10.1149/07101.0227ecst>; 2017 – M.V. Romeri "Considering Hydrogen Fuel Cells Powertrain as Power Generation Plant – 2017 review" (published January 2018) in "2nd AIEE Energy Symposium Conference Proceedings", Rome, Lumsa University. Available at: <http://www.aieeconference2017rome.eu/documents/Rome-Proceedings.pdf>; 2018 – M.V. Romeri "Consideration about Hydrogen and Fuel Cells in the Paris Agreement 1.5°C Perspective" (published January 2019) in "3rd AIEE Energy Symposium Conference Proceedings", Milan, Bocconi University. Available at: <http://www.aieeconference2018milan.eu/documents/AIEE_SYMPOSIUM_2018_proceedings.pdf>; 2019 – M.V. Romeri "The history could repeat itself: hydrogen-oxygen fuel cell is the 'game changer'" (published January 2020) in "4th AIEE Energy Symposium Conference Proceedings" Rome, Lumsa University. Available at: <http://www.aieeconference2019rome.eu/documents/AIEE_Symposium_Proceedings_4.pdf>.	Taken into account. It seems to be too granular and deepens the difficulty of LCOE calculations	MARIO VALENTINO ROMERI	Independent consultant	Italy
20621	73	1	73	9	A forthcoming paper, part of the EMF-33 IAM comparison concerning biomass and bioenergy use in climate change mitigation strategies (reference below), outlines the techno-economic parameterization of bioenergy technologies in IAMs, and its importance in climate change mitigation strategies, can add further data-points in table 6.8. An inclusion of IAM projections concerning costs (or comparison) may be interesting given thier importance in climate change mitigation strategies. The paper also breaks down levelised costs between (i) Capital and O&M, (ii) Feedstock, (iii) CDR costs/benefits from pricing carbon. Interestingly, the levelised costs in this paper largely match those in table 6.4 with the following additional insights: - IAMs show a larger range in the cost of bio-based electricity, with most models agreeing with the range presented in table 6.4. However in some cases IAMs can have significantly higher costs. - IAMs show an increase in levelized costs between 2030 and 2050, largely because of increasing feedstock costs (but of course this is scenario specific - low biomass demand scenarios show lower biomass costs). - Cost of Biomass+CCS decreases in IAMs due to the credit they get are assumed to get when GHG emissions are priced. - While the manuscript focuses on biomass and bioenergy, in the supple,entary material IAM results for all electricity production option (fossil+renewable) are included. DAIOGLOU, V., ROSE, S., BAUER, N., KITOUS, A., MURATORI, M., SANO, F., FUJIMORI, S., GIDDEN, M., KATO, E., KERAMIDAS, K., KLEIN, D., LEBLANC, F., TSUTSUI, J., WISE, M. & VAN VUUREN, D. in review. Bioenergy technologies and climate change mitigation pathways: Results from the EMF33 study. Climatic Change.	Accepted. The cost of bioenergy can be added.	Vassilis Daioglou	Copernicus Institute of Sustainable Development	Netherlands
36519	73	1	73	9	Supply of biomass feed stock is limited so cost of feed stock seems to be increased when more demand is appeared. However, cost in 2050 is lower than present cost. Is the contribution of technology development big enough to offset the increase of cots of feed stock supply?	Taken into account. The develpoment of biomass technology and feed stock are under much uncertainties. Feed stock is not considered when calculating LCOE for biomass energy technologies	Takashi Hongo	Mitsui & Co. Global Strategic Studies Institute	Japan

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
42967	73	1	73	9	I understand that "Table 6.8 Summary of cost and performance characteristics of key energy technologies" is just a quick sample of some of the levelized cost information you have gathered to date and it will be revised and updated for SOD-Draft. So I suggest to read and include also consideration and data analyzed in the recent reports prepared by the EIA: "Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2020" [February 2020; available at <https://www.eia.gov/outlooks/aeo/pdf/electricity_generation.pdf >] and by Hydrogen Council: "Path to Hydrogen Competitiveness: A Cost Perspective" [January 2020; available at <https://hydrogencouncil.com/wp-content/uploads/2020/01/Path-to-Hydrogen-Competitiveness_Full-Study-1.pdf >].	Accepted. We have updated the report.	MARIO VALENTINO ROMERI	Independent consultant	Italy
42969	73	1	73	9	In recent years I published different papers were 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. This solution, if rapidly adopted at scale level, seems to be able to give a contribution to the climate emergency challenge. However, this low-carbon solution has still not been considered in international energy and climate change debate. I suggest to consider the possibility to insert the 'H2FCPowertrain as power generation plant' in "Table 6.8 Summary of cost and performance characteristics of key energy technologies". References: 2015 – M.V. Romeri "Hydrogen and Fuel Cell: A Cinderella or a Disruptive Low-Carbon Solution?" at "2015 Fuel Cell Seminar & Energy Exposition", Los Angeles CA, USA. Available at ECST: <http://ecst.ecsdl.org/content/71/1/227> or <http://dx.doi.org/10.1149/07101.0227ecst>; 2017 – M.V. Romeri "Considering Hydrogen Fuel Cells Powertrain as Power Generation Plant – 2017 review" (published January 2018) in "2nd AIEE Energy Symposium Conference Proceedings", Rome, Lumsa University. Available at: <http://www.aieeconference2017rome.eu/documents/Rome-Proceedings.pdf>; 2018 – M.V. Romeri "Consideration about Hydrogen and Fuel Cells in the Paris Agreement 1.5°C Perspective" (published January 2019) in "3rd AIEE Energy Symposium Conference Proceedings", Milan, Bocconi University. Available at: <http://www.aieeconference2018milan.eu/documents/AIEE_SYMPOSIUM_2018_proceedings.pdf>; 2019 – M.V. Romeri "The history could repeat itself: hydrogen-oxygen fuel cell is the 'game changer'" (published January 2020) in "4th AIEE Energy Symposium Conference Proceedings" Rome, Lumsa University. Available at: <http://www.aieeconference2019rome.eu/documents/AIEE_Symposium_Proceedings_4.pdf>.	Taken into account. It seems to be too granular and deepens the difficulty of LCOE calculations	MARIO VALENTINO ROMERI	Independent consultant	Italy
8907	73	1	73	10	I am embarassed to read the figures in the table 6,8, published without specific comments. Once more, the end user is paying for a kWh, and he expects that the service wil be available 100% of the time. Comparig cost of one kWh available any time when needed (from hydro, geothermal, fossil, nuclear..) and a Wh available from time to time does not make sense. The table compare the costs of production, (under specific and unbalances commercial conditions), not the value of the kWh delivered when needed. Again, it's like comparing carrots and cabbage! At least, a comment must come with the table to clearly make the limit of the comparison.	Rejected. We consider the cost per kWh from the supply side rather than the customer side, and the customer must be paying a higher cost per kWh than the supply side.	Michel SIMON	Vice Président SFENRAL	France
8907	73	1	73	10	I am embarassed to read the figures in the table 6,8, published without specific comments. Once more, the end user is paying for a kWh, and he expects that the service wil be available 100% of the time. Comparig cost of one kWh available any time when needed (from hydro, geothermal, fossil, nuclear..) and a Wh available from time to time does not make sense. The table compare the costs of production, (under specific and unbalances commercial conditions), not the value of the kWh delivered when needed. Again, it's like comparing carrots and cabbage! At least, a comment must come with the table to clearly make the limit of the comparison.	Rejected. We consider the cost per kWh from the supply side rather than the customer side, and the customer must be paying a higher cost per kWh than the supply side.	Michel SIMON	Vice Président SFENRAL	France
9571	73	1			Check numbers in T 6.8 as they look inconsistent and sometimes incredible. Examples: gas with CCS is only marginally more expensive than without CCS today, but in future a wider gap; coal with 30%CCS is more expensive than 90%CCS; nuclear cost is almost a point estimate which cannot be true, and costs drop in future - a phenomenon not observed to date as is often discussed in literature on technological learning.	Data updated	Tom Kram	PBL (Fellow)	Netherlands
37407	73	1			table 6.8: cost estimate for gas with ccs not consistent with current assessments in the literature. For an overview, see figure 3 in https://climateanalytics.org/media/report_coal_phase_out_2019.pdf	Data updated	Michiel Schaeffer	Climate Analytics	Netherlands

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
11719	73	4	73	5	First. Something is strange with coal LCOE. In 2050 the cheapest coal technology is "Coal", and the most expensive one is "Coal with 30% CCS" while "Coal with 90% CCS" is cheaper than case of 30% CCS. Second. International Energy Agency World Energy Outlook 2019 compares LCOE of different technologies in 2020 in the US, the EU, China and India. LCOE of wind onshore is 60-90 $/MWh, LCOE of wind offshore is 115-150 $/MWh, LCOE of solar is 50-120 $/MWh, LCOE of new gas projects is 50-90 $/MWh, LCOE of existing gas projects is 30-80 $/MWh, LCOE of new coal projects is 60-100 $/MWh, LOCE of existing coal projects is 35-50 $/MWh. This is fundamentally different result both in terms of cost and the relative expensiveness of technologies.	Taken into account. We again check the data given by EIA 2019, 30% CCS is indeed more expensive than 90% CCS. LCOE of technology varies from country to country, so we provide a range of LCOE.	Andrey Kolpakov	Institute of Economic Forecasting of the Russian Academy of Sciences	Russian Federation
27947	73	4	73	5	The nuclear costs in this table are much lower than in Lazard (2019), which has the mean nuclear cost as $15.5/MWh. Please correct. Please use a consistent dataset (e.g., Lazard, 2019) for everything. Also, CCS costs at, for example, Petra Nova, were $4000/kW, higher than the coal plant itself, so please don't lowball CCS costs either.	Data updated	Mark Jacobson	Stanford University	United States of America
29465	73	4	73	5	A report by IEAGHG (Towards Zero Emissions CCS in Power Plants Using Higher Capture Rates or Biomass) has demonstrated that very high capture fractions (>99%) are achievable with little additional marginal cost of capture. In the context to deep emissions cuts, it is unlikely that future CCS plants will be deployed with 90% capture fractions when economics support much higher capture fractions. Therefore including a 95% or 99% CCS line is important as these will represent the likely design specifications for future CCS facilities.	Taken into account. The development of CCS is of much uncertainties in the future.	Eve Tamme	Global Carbon Capture and Storage Institute	Belgium
45379	73	4	73	5	Final high data point in "Coal with 30% CCS 131-132 92.5-138.2 89.1-185.2" line seems incorrect	Data updated	Deborah Knuckey	Published energy journalist plus consultant for renewable energy development and finance companies through Kiterocket	United States of America
11719	73	4	73	5	First. Something is strange with coal LCOE. In 2050 the cheapest coal technology is "Coal", and the most expensive one is "Coal with 30% CCS" while "Coal with 90% CCS" is cheaper than case of 30% CCS. Second. International Energy Agency World Energy Outlook 2019 compares LCOE of different technologies in 2020 in the US, the EU, China and India. LCOE of wind onshore is 60-90 $/MWh, LCOE of wind offshore is 115-150 $/MWh, LCOE of solar is 50-120 $/MWh, LCOE of new gas projects is 50-90 $/MWh, LCOE of existing gas projects is 30-80 $/MWh, LCOE of new coal projects is 60-100 $/MWh, LOCE of existing coal projects is 35-50 $/MWh. This is fundamentally different result both in terms of cost and the relative expensiveness of technologies.	Taken into account. We again check the data given by EIA 2019, 30% CCS is indeed more expensive than 90% CCS. LCOE of technology varies from country to country, so we provide a range of LCOE.	Andrey Kolpakov	Institute of Economic Forecasting of the Russian Academy of Sciences	Russian Federation
27947	73	4	73	5	The nuclear costs in this table are much lower than in Lazard (2019), which has the mean nuclear cost as $15.5/MWh. Please correct. Please use a consistent dataset (e.g., Lazard, 2019) for everything. Also, CCS costs at, for example, Petra Nova, were $4000/kW, higher than the coal plant itself, so please don't lowball CCS costs either.	Taken into account. The LCOE for nuclear is from Leigh and EIA 2019. The LCOE of nuclear given by Lazard is 118-192 $/MWh, much higher than the 89-92 $/MWh we referenced. We will refer to all the literature and give a reasonable range of LCOE.	Mark Jacobson	Stanford University	United States of America
29465	73	4	73	5	A report by IEAGHG (Towards Zero Emissions CCS in Power Plants Using Higher Capture Rates or Biomass) has demonstrated that very high capture fractions (>99%) are achievable with little additional marginal cost of capture. In the context to deep emissions cuts, it is unlikely that future CCS plants will be deployed with 90% capture fractions when economics support much higher capture fractions. Therefore including a 95% or 99% CCS line is important as these will represent the likely design specifications for future CCS facilities.	Taken into account. The development of CCS is of much uncertainties in the future.	Eve Tamme	Global Carbon Capture and Storage Institute	Belgium
45379	73	4	73	5	Final high data point in "Coal with 30% CCS 131-132 92.5-138.2 89.1-185.2" line seems incorrect	Taken into account. The cost of the technology is more controversial, and we again confirmed the costs are from the literature NREL 2019 and EIA 2019. The cost in year 2050 is incremental in terms of growth rate.	Deborah Knuckey	Published energy journalist plus consultant for renewable energy development and finance companies through Kiterocket	United States of America
12401	73	4	73	9	Surprices that levelized cost of electricity from 2019-2050 for coal and gas technologies with CCS increases, which is oposite to projections for development and introduction of all other new technologies.	Data updated	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
29459	73	4	73	9	Although the use of the LCOE as a technology valuation tool has a host of benefits, there are limitations to the LCOE such as that it does not reflect the value provided by intermittent and dispatchable sources of electricity as well as the impact on the system when introducing a particular technology. The text can be changed to adequately reflect this and any additional insights provided by whole systems cost analysis for the different power generation technologies.	Taken into account. That'a a good comment. Intermittent renewables may be accompanied by other cost increases when they are grid-connected. LCOE does not reflect system-wide costs.	Eve Tamme	Global Carbon Capture and Storage Institute	Belgium

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
12401	73	4	73	9	Surprices that levelized cost of electricity from 2019-2050 for coal and gas technologies with CCS increases, which is oposite to projections for development and introduction of all other new technologies.	Accepted. The minimum value of LCOE has decreased and the maximum value has increased, resulting in a wider range of LCOE costs	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
29459	73	4	73	9	Although the use of the LCOE as a technology valuation tool has a host of benefits, there are limitations to the LCOE such as that it does not reflect the value provided by intermittent and dispatchable sources of electricity as well as the impact on the system when introducing a particular technology. The text can be changed to adequately reflect this and any additional insights provided by whole systems cost analysis for the different power generation technologies.	Taken into account. That'a a good comment. Intermittent renewables may be accompanied by other cost increases when they are grid-connected. LCOE does not reflect system-wide costs.	Eve Tamme	Global Carbon Capture and Storage Institute	Belgium
11547	73	4			for 2019 lower LCOE for PV already exist. What currency year is used? The used references ar up to 5 years old. Please use current ones.	Accepted	Arnulf JÄGER-WALDAU	European Commission, JRC	Italy
1229	73	4			Include detailed process of levelized cost calculation	Data updated, the LCOEs are obtained from the literature. Some assumptions are list below the table.	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
1231	73	6			Annual growth rate of what?	It is annual growth rate of LCOE of each technology	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
1233	73	7			Is it BECCS or biomass with CCS?	BECCS equals to biomass with CCS here.	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
8997	73	11	80	46	I would like to share my perspective on the structure of subsection 6.5 as a whole. After reading it a few times, I still feel that something is missing here. I think that the subsection would benefit greatly from introducing the intersections between energy and climate first. These intersections are numerous, including aspects that are covered in the report (e.g. impacts on long-term potentials), aspects that are not yet part of the report but have been researched (such as the impact of climate variability on energy system operation) and aspects that no one has considered yet. In particular the last category constitute a potentially major risk because climate change may lead to unanticipated impacts in metrics that we are currently not looking at.	Taken into account. The section has been revised to clarify the focus on climate change impacts on the energy system. A new figure has also been added.	Jan Wohland	ETH Zürich	Switzerland
15615	73	11	81	29	6.5. Climate Impacts on the Energy Systems. Good but can be improved by re-organising the impact indicators (High wind speeds, Vegetation, Lightning, Snow& Icing, flooding, thermal effects) on the various components of the energy system: Sources/ Resources; Generation/Production; transmission/transportation; distribution/supply/retailing; consumption/use.	Taken into account. Please see answer to issue 15613	Joseph Essandoh-Yeddu	Energy Commission	Ghana
26593	73	11	81	29	There is the opportunity to mine the urban heat island in combination with interseasonal thermal storag to supply building heating. Reference: The geothermal potential of urban heat islands. Ke Zhu1, Philipp Blum2, Grant Ferguson3, Klaus-Dieter Balke1 and Peter Bayer4. Published 12 October 2010 • IOP Publishing Ltd	Rejected - outside the scope of the chapter. Geothermal energy covered in section 6.4	Peter North	Calorem Ltd, Imperial College (part-time PhD student)	United Kingdom (of Great Britain and Northern Ireland)
47743	73	11	81	29	Please double-check this section on climatic factors affecting energy systems against WGI CH12 (particularly section 12.3), as there was an effort made there to identify the many connections between specific climatic impact factors (e.g., heatwaves, pluvial flooding, permafrost, severe storms) and energy sector assets (under the cities and major infrastructure sector). Figure 6.29, in particular, would be helpful to link with WGI CH12.	Needs re-evaluation after text is written	Alex Ruane	NASA Goddard Institute for Space Studies	United States of America
37863	73	11			This section 6.5 fails to mention the impacts of climate change on energy demand, in particular space heating and cooling. This can be very relevant, e.g. Levesque et al. (https://doi.org/10.1016/j.energy.2018.01.139)	Taken into account. Climate change impacts on electrcity consumption are now presented in 6.5.2. The suggested reference has been added. However, the energy consumption is covered in more detail in Chapter 5.	Gunnar Luderer	Potsdam Instittute for Climate Impact Research	Germany
15613	73	12	73	81	6.5. Climate Impacts on the Energy Systems. Good but can be improved by re-organising the impact indicators (High wind speeds, Vegetation, Lightning, Snow& Icing, flooding, thermal effects) on the various components of the energy system: Sources/ Resources; Generation/Production; transmission/transportation; distribution/supply/retailing; consumption/use.	Taken into account. The section has been revised to clarify that the focus is on climate change impacts and not how various weather phenomena affect the power system.	Joseph Essandoh-Yeddu	Energy Commission	Ghana

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
15575	73	12	81	29	Climate Impacts on the Energy System: This subchapter should also cover the fossil fuels; coal and oil. If impact is non-existent or none, it should be indicated. In my opinion, the Energy Sources and Conversion should be a subheading of its own just like 6.4 which is Mitigation Options In General the Energy System should be clearly elaborated. All the information is there but it should be re-arranged this way, say Thermal Energy Systems (from Resource/source; to generation/production; to transmission/transportation and distrubution; and to consumption/use), value chain, climate challenges, Mitigation Actions etc.) Nuclear Power Systems same as above Renewable Energy Systems same as above Traditional Biomass, this very important since its still massive use in poor and developing countries for largely cooking and heating. Energy Storage Technologies.	Taken into account. The structure of 6.5 is revised with the aim to make it clearer. Climate change impacts on thermal power plants are now presented in 6.5.1.6. The various ways climate change affects fossil fuels are now summarized in a table at the start of the section.	Joseph Essandoh-Yeddu	Energy Commission	Ghana
17017	73	12	81	29	I think that section 6.5 gives a comprehensive list of the climate's impacts on energy, but it is just a generalization of the concept, and this section lacks specific data support for many results. We do not know the impact of these climates on various energy How big is it? I suggest adding data as much as possible to support it.	Taken into account. A new table has been added to try to quantify the effect of various climate changes into the energy system.	Qing YANG	Harvard University	China
2637	73	18	73	24	Are you sure this clever classification in 3 branches will cover every cases ? The example I have in mind is the strong impact on the cryosphere, specifically illustrated by the fact that most continental glaciers will shrink and possibly disappear altogether. While I do not know about the snow, it seems likely that the overall stock of solid water accumulated in winter monthes will become smaller and short-lived. This will be reflected in reduced flows of rivers in late spring and summer. What will then happen to hydropower plants ? What will happen to nuclear plants lacking cooling capacities ? Maybe these effects are second order? they ought at least to be mentioned and assessed.	Taken into account. The subsections of 6.5 have been revised, and the text in the beginning of 6.5. has been updated. Impacts on hydro power are discussed in 6.5.1.1, and impacts on thermal generation in 6.5.1.6 (new subsection). Flooding and sea level rise impacts on power system vulnerability are discussed in 6.5.3.	Philippe Waldteufel	CNRS/IPSL/LATMOS	France
8975	73	18	73	24	I think that categorizing climate impacts on energy is a very good idea. However, I see two problems with the categories presented here. First, they seem to focus on climate CHANGE impacts, whereas the first sentence talks about climate impacts in general (which would also include impacts from climate variability). Second, the categories substantially overlap. A change in the seasonality of renewable generation (example for category 2) is also a direct change of the geophysical potential in summer/winter (definition of category 1). Maybe it would be more helpful to categorize like this: 1) impacts of climate variability on energy, 2) impacts of climate change on energy, 2b) impact of climate change on extreme events that are relevant for energy.	Taken into account. The section name is revised to focus on "climate change impacts" to clarify that this section deals with climate change impacts (not with variability in renewable energy in general, except if this variability is expected to change due to climate change). We agree that the categories (1), (2) and (3) overlap. The subsections and structure of 6.5 are thus revised.	Jan Wohland	ETH Zürich	Switzerland
20623	73	18	73	24	Cocnerning the impacts on the energy system, what about changes concerning energy demand? For instance demand for space heating and cooling due to changes in ambient temperature. These can be quite extreem in some regions where temperature change is greater than the global mean. Isaac, Morna, and Detlef P. Van Vuuren. "Modeling global residential sector energy demand for heating and air conditioning in the context of climate change." Energy policy 37.2 (2009): 507-521. Hadley, Stanton W., et al. "Responses of energy use to climate change: A climate modeling study." Geophysical research letters 33.17 (2006).	Taken into account. Climate change impacts on electricity consumption are discussed in section 6.5.2, and the structure of 6.5 is clarified.	Vassilis Daioglou	Copernicus Institute of Sustainable Development	Netherlands
31837	73	18	73	24	The three categories described here do not cover all the ways in which climate change may impact the energy system (and indeed some of them are discussed later). E.g., erratic precipitation leading to water shortages leading to problems for thermal power generation, or glacial melt patterns changing and influencing hydro power plants. So, it may be better to broaden the three categories a bit more to include such points.	Taken into account. The catogories have been reviewed and the text in 6.5 revised. Impacts on hydro power are discussed in 6.5.1.1; impacts on thermal generation are discussed in 6.5.1.6.	Ashok Sreenivas	Prayas (Energy Group)	India
8977	73	24	73	25	The following sentence needs correction: “The various time scales of the changes in the energy system climate change do not occur in isolation”	Taken into account. The sentence has been revised.	Jan Wohland	ETH Zürich	Switzerland
10147	73		73		Table 6.8 Summary of cost and performance characteristics of key energy technologies. This table is only focussing on electricity technologies, whereby the most important electricity production technology of the future is even not in this table, that is the fuel cell!!! But there is a whole range of other key energy technologies, such as all the hydrogen production technologies (SMR, ATR, Gasification, Electrolysis, Pyrolysis, Fotolysis, etc.), Heat production technologies (furnaces, boilers, heat pumps, heat exchangers, etc.) or Fuel production technologies (Refineries, Fisher Tropsch, Chemical synthesis, etc.!!!!	Partially accepted. We have added some technologies, such as SMR with CCS, ATR with CCS, PEM Electrolyser, Alkaline electrolyser, Solid oxide electrolyser, etc.	Ad van Wijk	Technical University Delft	Netherlands
16683	73				Table 6-8 is actually 6-16	Accepted	Jean Louis Bobin	Sorbonne universités Paris	France

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
16685	73				Table 6-8 (6-16) the stated levelized costs of solar PV and wind are misleading. Several factors that might increase such costs. Due to poor capacity factors: 1) installed plants are oversized, 2) electric transport grid should accomodate the oversized rated power. Due to intermittency in a 100% renewable system, storage is mandatory an the vorresponding cost should be accounted for.	We only consider the LCOE for power generation technologies at this moment. We will think about how to include the storage cost.	Jean Louis Bobin	Sorbonne universités Paris	France
20777	73				Table 6.8. the LCOE of Coal maybe is overrated. And it is unreasonable the cost of 30% CCS is higher than 90% CCS.	Data updated	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	China
5217	74	1	74	3	The concrete width of the lines seem arbitrary. Is this figure neccessary?	Accepted. A new figure/table replaces this figure.	Andreas Oberheitmann	FOM University of Applied Sciences	Germany
28897	74	1	74	3	I know you want to explain many climate parameters in easy way,and although I can understand it easily but many new questions arise. E.g. rainfall may bring positive impact for usefull for hydropower, but high rainfall will also brings flood. Should it be "green" why not "green" and "brown"?	Accepted. A new figure/table replaces this figure.	Marissa Malahayati	National Institute for Environmental Studies	Japan
8979	74	2	74	7	I understand that this figure is preliminary and will be improved. Nevertheless, I see some fundamental issues with it that I would like to share. It is not clear what "positive effects" and "negative effects" exactly mean and how importance is measured and translated into the line thickness. Moreover, some of the statements made in the figure might be hard to justify. For example, the figure implies that changes in wind speeds have a positive effect on wind power. While this statement might be correct in some cases, it is obviously wrong in other cases as can be seen, for example, from the regions of declining wind speeds in Karnauskas et al (2018) or the fact that wind speeds become more homogeneous in Europe hindering inter-country balancing (Wohland et al., 2017). The anticipated changes of climate change therefore sometimes have a negative effect on wind power which contradicts the Figure. I therefore think that this Figure needs some cenceptual improvements. References: Karnauskas, K. B., Lundquist, J. K. & Zhang, L. Southward shift of the global wind energy resource under high carbon dioxide emissions. Nature Geosci 11, 38–43 (2018). Wohland, J., Reyers, M., Weber, J. & Witthaut, D. More homogeneous wind conditions under strong climate change decrease the potential for inter-state balancing of electricity in Europe. Earth Syst. Dynam. 8, 1047–1060 (2017).	Accepted. A new figure/table replaces this figure.	Jan Wohland	ETH Zürich	Switzerland
24345	74	3	74	3	The increase in mean wind speed may be a good thing for wind power but climate warming will also increase turbulence and so the wind speed fluctuation. The quick change of velocity can have a dramatic influence on the wind power injected on the grid. (Is it included in extreme precipitation ?)	Rejected - not supported by the peer-reviewed published literature	Alan BURLOT	Commissariat à l'énergie atomique et aux énergies alternatives	France
26973	74	3			The figure is not complete. The effect of climate related drought on dust storms and their effect on solar PV performance and their damage to the electricity distribution grid is dominant. These two factors must be included in the image.	Accepted. A new figure/table replaces this figure.	Hossein Khajehpour	Energy Engineering Department, Sharif University of Technology	Iran
31839	74	4	74	7	Are "positive effect" and "negative effect" meant to indicate "positive correlation" and "negative correlation", i.e. if wind speed increases, wind power generation will increase; and if cloud cover increases solar PV geenration will decrease?	Accepted. A new figure/table replaces this figure.	Ashok Sreenivas	Prayas (Energy Group)	India
28357	74	4			what is the difference between rainfall and extreme precipitation? Maybe can consider to use rainfall and draught instead	Accepted. A new figure/table replaces this figure.	Hoy Yen Chan	ASEAN Centre for Energy	Malaysia
28359	74	4			in fact ranfall will bring impacts on solar plant. The panels are not high from the ground, during flood, the panel will be damaged, especially when the sea level rise to the extent that qould cause inundation	Rejected - beyond the mandate of the report	Hoy Yen Chan	ASEAN Centre for Energy	Malaysia
28361	74	4			in the text the figure was mentioned as Figure 6, while the diagram is Figure 6.29	editorial	Hoy Yen Chan	ASEAN Centre for Energy	Malaysia
1235	74	5			Include in the text why there is a green line/positive effect between wind speed and wind power? Similarly explain the other cases in the figure	Accepted. A new figure/table replaces this figure.	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
1237	74	6			Include how you came up with the width of the lines? Is the width based on: 1) mathematical calculations, or 2) subjective choice? any subjective choice does not ensure a robust analysis.	Accepted. A new figure/table replaces this figure.	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
20625	74	8	77	19	In this section it is worth considering a manuscript that is currently under review. The paper uses the results from 5 climate models to determine the impacts of cliamte change for renewable energy (solar, wind, hydropwer, 1st generation and advanced biomass). It then runs these impacts through an energy system model (TIMER, part of the IMAGE IAM) to determine the impact on regional energy systems. Gernaat et al. Climate impacts on renewable energy supply, Under Review	Taken into account. Once the article is published it will be considered.	Vassilis Daioglou	Copernicus Institute of Sustainable Development	Netherlands
9573	74	8			the more recent, very relevant work of David Gernaat (PBL, the Netherlands) is missed in this section, please redress.	Taken into account. Once the article is published it will be considered. See response to 20625	Tom Kram	PBL (Fellow)	Netherlands

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
1545	74	9	74	16	The text mentions there is few literature on the future impact of climate change on renewable energy. An example of a recent scientific study is: Gernaat (2019). The role of renewable energy in long-term energy and climate scenarios. D. Gernaat, June 2019. https://dspace.library.uu.nl/handle/1874/381146.	Taken into account. The publications will be considered once accepted in peer-review publication	Paul Vethman	PBL Netherlands Environmental Assessment Agency	Netherlands
17019	74	10	74	10	"(see summary in Figure 6.)"? is it Figure 6.29? It needs to be checked carefully here.	editorial	Qing YANG	Harvard University	China
35735	74	10	74	10	"Figure 6.29" instead of just "Figure 6".	editorial	Frank Kaspar	Deutscher Wetterdienst	Germany
1239	74	16			is the word 'feedback' correct?	editorial	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
31841	74	17	74	17	Does IPCC treat all hydro power as renewable? This is a controversial issue and IPCC should reconsider this.	Rejected.At IPCC hydropower is treated as a reneweable source of energy.	Ashok Sreenivas	Prayas (Energy Group)	India
43849	74	17			SROCC chp 2 indicated the potential consequences for hydropower with cryosphere decline - this could be referenced here	Accepted. The citation is included	Hans Poertner and Elvira Poloczanska	Alfred-Wegener-Institut	Germany
6391	74	22	74	22	Please make more clear what ‘overall runoff’ precisely means	Accepted. The word "overall" is deleted from the text	Sciacovelli Adriano	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
42373	74				Figure 6.29, you may need to included drought on this figure. It is very important factors that can affect thermal and hydro power plant output.	Accepted. A new figure/table replaces this figure. The new figure/table is more detailed	Solomon Asfaw	LUT University	Finland
17409	75				It is better to give an example of the effect of climate change on water demand (eg increasing in agricultural water demand due to increased water demand of plants).	Editorial. I don't think it is necessary to include the suggested text. Agriculture is mentioned before in the text as a water demanding activity. I'm not sure if it is necessary to motivate more than writing editorial	Zeyaeyan Sadegh	Islamic Republic of Iran Meteorological Organization (IRIMO)	Iran
20779	75				Figure 6.30. the meaning of color need to be explained.	Accepted. A new figure/table replaces this figure.	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	China
45461	75				What is the color scale in the figure? It is difficult to review the content wihout this information.	Accepted. A new figure/table replaces this figure.	Girija Parthasarathy	Thermo King	United States of America
45463	75				Figure 6.29 (rainfall having positive effect on hydropower) and conclusions presented in line 25-33 about hydropower reduction in page 75 conflict - what is the explanation?	Accepted. A new figure/table replaces this figure. The new figure provides more details and in compatible with the conclutions presented	Girija Parthasarathy	Thermo King	United States of America
38009	76	8	76	11	This paragraph is enitrely lacking in objectivety and is not factually correct, recomded it being deleted or substantially re-writing. In particualr, 'These stations are considered more sustainable if compared to large ones due to their smalleer environmetal impact.' is a sweeping generalisation and over-simplifcation.	Taken into consideration. The paragraph has been modified.	Atle Harby	SINTEF Energy Research	Norway
38021	76	9	76	10	The sentence "These stations are considered more sustainable if compared to large ones due to their smaller 10 environmental impact." about small hydro is not documented and I find it flaw. Large hydro with reservoirs have a much better chance to become sustainable than small hydro that often have are marginally above break-even or have subvention support. This requires of course that large hydro follows international standards for sustainability, for instance IHA Sustainability Assessment Protocol (https://www.hydropower.org/hydropower-sustainability-assessment-protocol). Small hydro and run-of-river hydro also has the drawback that they cannot store water and have to produce energy when there is available water, just like wind and solar energy that cannot be dispatched and regulated	Taken into consideration. The paragraph has been modified.	Atle Harby	SINTEF Energy Research	Norway

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
8981	76	12	76	29	I find subsection 6.5.1.2 very important. However, it is also difficult to read as it lacks a clear line of reasoning. While the title (wind energy) suggests that all sorts of climate change impacts on wind energy are addressed, the subsection only covers long-term potentials and extreme events. Changes in spatio-temporal variability and multidecadal climate variability are currently not addressed. Moreover, I think that this section would benefit from acknowledging more recent work. As a suggestion, maybe it makes sense to restructure this paragraph like this: (1) Limited impacts of climate change on wind energy potentials globally and regionally (e.g., Tobin 2015 & 2016, Reyers 2016) (2) Changes in the spatial patterns of wind energy potentials (3) Changes in spatio-temporal variability of wind energy (e.g., Wohland 2017) (4) Changes in extremes References: Tobin, I. et al. Assessing climate change impacts on European wind energy from ENSEMBLES high-resolution climate projections. Climatic Change 128, 99–112 (2015). Tobin, I. et al. Climate change impacts on the power generation potential of a European mid-century wind farms scenario. Environ. Res. Lett. 11, 034013 (2016). Reyers, M., Moemken, J. & Pinto, J. G. Future changes of wind energy potentials over Europe in a large CMIP5 multi-model ensemble. Int. J. Climatol. 36, 783–796 (2016). Wohland, J., Reyers, M., Weber, J. & Witthaut, D. More homogeneous wind conditions under strong climate change decrease the potential for inter-state balancing of electricity in Europe. Earth Syst. Dynam. 8, 1047–1060 (2017).	Taken into account. The section has been revised to clarify the focus on climate change impacts on the energy system. Effects on variability will also be considered. Some of the references have been considered.	Jan Wohland	ETH Zürich	Switzerland
2157	76	13			The figure seems to indicate wind energy potential will increase?	Accepted. A new figure/table replaces this figure.	Amy Townsend-Small	University of Cincinnati	United States of America
20399	76	30	77	12	results in Emodi et al. (https://www.sciencedirect.com/science/article/pii/S0048969719318297) may deliver a more recent view	Taken into account. The publication will be considered when revising the text.	Christian Breyer	LUT University	Finland
8983	76	31	76	39	The first three sentences lack references and do not discuss the uncertainty and inter-model spread.	Taken into account. The text will be revised including references.	Jan Wohland	ETH Zürich	Switzerland
6045	76	32	76	33	…including SE N. America…' and ….. '….N. S. America…'	editorial	SAIK PENG, CASEY NGO	R-SYNC TECHNICAL RESOURCES SDN. BHD.	Malaysia
8985	76	41	76	45	The first sentence is very similar to the findings of Jerez et al. (2015). Please cite them properly. I would suggest to clarify which scenario you are referring to. I assume that we are talking about 4 different rcp scenarios here. I would suggest to also discuss Müller (2019) for a more complete picture. References: Jerez, S. et al. The impact of climate change on photovoltaic power generation in Europe. Nat Commun 6, 10014 (2015). Müller, J., Folini, D., Wild, M. & Pfenninger, S. CMIP-5 models project photovoltaics as a no-regrets investment in Europe irrespective of climate change. Energy 171, 135–148 (2019).	Accepted. Both references will be taken into account in the revised manuscript.	Jan Wohland	ETH Zürich	Switzerland
14205	77	3	77	3	"the estimated future production changes by CSP" Please take into account that real capacity factors of CSP are typically in the range of 25-30%, which are values much lower than the ones typically considered in theoretically studies, check: de Castro, C., Capellán-Pérez, I., 2018. Concentrated Solar Power: Actual Performance and Foreseeable Future in High Penetration Scenarios of Renewable Energies. Biophys Econ Resour Qual 3, 14. https://doi.org/10.1007/s41247-018-0043-6	Noted. The citation makes the claim that electricity generation in actual real-world systems is substantially lower than in modeled systems. In this section we focus on the change in output due to a changing climate -- we would expect the same percentage change regardless of whether the capacity factor is in the 0.15-0.3 range described in this article or higher as in modeled systems.	Iñigo Capellán-Pérez	University of Valladolid	Spain
26975	77	12			Before ending the solar section, the indirect climate change impact on the solare radiation as well as the PV efficiencies due to increases dust storms resulted from the intensified drouhgts must be mentioned in a phrase. (https://doi.org/10.1186/s40807-017-0043-y, https://doi.org/10.1016/j.rser.2019.109415)	Taken into account. The effect is already recorded in the new table in this section.	Hossein Khajehpour	Energy Engineering Department, Sharif University of Technology	Iran
28445	77	13	77	19	I urge authors to consider the Young paper on the wave resource trend: Young, I.R. and Ribal, A., 2019. Multiplatform evaluation of global trends in wind speed and wave height. Science, 364(6440), pp.548-552.	Rejected - outside the scope of the chapter. The section deals with future changes not observed trends.	Matt Lewis	Bangor 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
28447	77	13	77	19	Tidal energy is also to be affect by weather, thus potential changes to wave claimtes and storm surges for stream and rnage respecitively: Lewis, M.J., Neill, S.P., Hashemi, M.R. and Reza, M., 2014. Realistic wave conditions and their influence on quantifying the tidal stream energy resource. Applied Energy, 136, pp.495-508. and Lewis, M.J., Angeloudis, A., Robins, P.E., Evans, P.S. and Neill, S.P., 2017. Influence of storm surge on tidal range energy. Energy, 122, pp.25-36.	Rejected - outside the scope of the chapter. Lack of room to include every detail.	Matt Lewis	Bangor University	United Kingdom (of Great Britain and Northern Ireland)
20331	77	30	78	4	the literature overview on highly renewable energy systems is weak. Major revision is required for this part. Major literature is missing. The overview article on most 100% renewables articles of Hansen et al. (https://www.sciencedirect.com/science/article/pii/S0360544219304967) is fully missing. The only 100% renewable article in full hourly resolution on global scale Bogdanov et al. (https://www.nature.com/articles/s41467-019-08855-1) is fully missing - it is BTW the only 100% RE article on Nature/Science level. It is also missing that there are several global 100% renewable studies, as tabulated in Breyer et al. (https://www.iaee.org/eeep/article/305). All these articles tackle highly renewable energy systems and provide a broad overview.	Taken into account. Based on comment number 17067, Section 6.5 is revised to focus on climate change impacts on power and energy systems. 100 % renewable energy systems are addressed in section 6.6.	Christian Breyer	LUT University	Finland
42019	77	30	80	46	6.5.2. and 6.5.3. are very similar. There are overlaps beween the contents. Perhaps clustering them would convey a more clear impression	Taken into account. The subsections have been revised with the aim to give a clearer distinction between them.	Francisco Javier Hurtado Albir	European Patent Office	Germany
8987	77	32	78	33	The second sentence (“One implication is the structure and operation of future, low-carbon electric power systems heavily-dependent on solar and wind power.“) is not clear to me. Do you mean: “One reason for this is the increased weather-dependency of future low-carbon power systems”? If yes, I suggest to rephrase and to link to the relevant literature (e.g., Bloomfield 2016, Staffell 2016). Bloomfield, H. C., Brayshaw, D. J., Shaffrey, L. C., Coker, P. J. & Thornton, H. E. Quantifying the increasing sensitivity of power systems to climate variability. Environ. Res. Lett. 11, 124025 (2016). Staffell, I. & Pfenninger, S. The increasing impact of weather on electricity supply and demand. Energy 145, 65–78 (2018).	Taken into account. The sentence is revised and suggested references have been added.	Jan Wohland	ETH Zürich	Switzerland
17067	77	33	77	37	Should these references not be treated in section 6.4.6.2? Or in 6.6?	Taken into account. Section 6.5 is revised to focus on climate change impacts on power and energy systems. General consideration of energy systems is not treated in 6.5, and thus these references and the related sentence is removed from 6.5. 100 % renewable energy systems are addressed in section 6.6.	Kornelis Blok	Delft University of Technology	Netherlands
8989	77	33	78	37	It is not clear what “these systems” are. I suggest to rephrase to: “The feasibility of fully-renewable energy systems is a central topic in the context of climate change mitigation (citations).“ I think it would be helpful to also discuss the cited studies which generally imply that fully-renewable system are (at least technologically) feasible! The sentence “The models reviewed or used in these assessments are highly complex and thus many simplifications and assumptions are made (Brown et al. 2018), which increases their uncertainty” is not clear to me. If the models were highly complex, we would not need simplifications. I think you might want to say that the the complexity of the real world is only partly captured in the models and therefore we need simplifications. There are at least three more studies that “consider how climate change can affect the availability and variability of low-carbon supply options”. They are Schlott (2018), Weber (2018), Wohland (2017). This somewhat contradicts your claim made in lines 37-39. Maybe it would be accurate to say that there is a limited but growing number of studies in this area. References Schlott, M., Kies, A., Brown, T., Schramm, S. & Greiner, M. The impact of climate change on a cost-optimal highly renewable European electricity network. Applied Energy 230, 1645–1659 (2018). Weber, J. et al. Impact of climate change on backup energy and storage needs in wind-dominated power systems in Europe. PLoS ONE 13, e0201457 (2018). Wohland, J., Reyers, M., Weber, J. & Witthaut, D. More homogeneous wind conditions under strong climate change decrease the potential for inter-state balancing of electricity in Europe. Earth Syst. Dynam. 8, 1047–1060 (2017).	Taken into account. Considering the first 2 paragraphs of the comment: Based on comment number 17067, Section 6.5 is revised to focus on climate change impacts on power and energy systems. 100 % renewable energy systems are addressed in section 6.6. The suggested references are added and the text is revised.	Jan Wohland	ETH Zürich	Switzerland

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
17081	77	35	77	37	I think this sentence is not a reflection of the Brown et al. 2018 paper (for transparency: I am a co-author). Models are complex, yes necessarily. But the paper rather expresses what we know about energy systems highly dependent on renewable sources, rather than the uncertainties and simplfications.	Taken into account. Based on comment number 17067, Section 6.5 is revised to focus on climate change impacts on power and energy systems. General consideration of energy systems is not treated in 6.5, and thus these references and the related sentence is removed from 6.5. 100 % renewable energy systems are addressed in section 6.6.	Kornelis Blok	Delft University of Technology	Netherlands
27917	77	37	77	39	"..few of the 100% renewable power system assessments consider how climate change can affect the availability and variability of low carbon supply options." Please state that the following two studies do account for 2050 climate condition feedbacks to wind and solar resources at the 30-second resolution (for 3 and 5 years, respectively) in 100% renewable scenarios for 143 and 139 countries, respectively, as determined from global climate model simulations: 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. https://web.stanford.edu/group/efmh/jacobson/Articles/I/WWS-50-USState-plans.html and 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, https://doi.org/10.1016/j.renene.2018.02.009, https://web.stanford.edu/group/efmh/jacobson/Articles/I/CombiningRenew/WorldGridIntegration.pdf	Taken into account. 100% renewable energy systems are addressed in section 6.6. It is not clear that these publications actually adress the changes to 100% renewables in 2050.	Mark Jacobson	Stanford University	United States of America
8991	78	2	78	4	To solidify this argument, I suggest to put the following sentence into context by comparing with the results of Reyers who also investigated climate change impacts on seasonality and Wohland (2019) who investigate multidecadal variability of seasonality in wind power generation. “In (Carvalho et al. 2017), wind generation is projected to decrease mainly in summer and autumn, with generation in winter expected to increase northern-central Europe and a decrease in the southernmost Europe.” Reference: Reyers, M., Moemken, J. & Pinto, J. G. Future changes of wind energy potentials over Europe in a large CMIP5 multi-model ensemble. Int. J. Climatol. 36, 783–796 (2016). Wohland, J., Omrani, N. E., Keenlyside, N. & Witthaut, D. Significant multidecadal variability in German wind energy generation. Wind Energ. Sci. 4, 515–526 (2019).	Taken into account. Both references are added and text revised accordingly	Jan Wohland	ETH Zürich	Switzerland
6441	78	5	78	9	https://www.sciencedirect.com/science/article/pii/S0921800916301306	Taken into account. The reference is added and text revised accordingly	Paul Neetzow	Humboldt-Universität zu Berlin	Germany
44783	78	5	78	9	For nuclear power plants near the sea or large lakes there are several options for how to mitigate such effects. In lack of peer reviewed literature, here are two texts on the matter. Ref 1: D. Westlén (2018), Nuclear power and high sea water temperatures. Analysgruppen, https://www.analys.se/engelska/publications/nuclear-power-high-sea-water-temperatures/ Ref 2: S. Qvist (2019) Curtailment of nuclear power output during extreme heat waves: The European case. Energy for Humanity, http://energyforhumanity.org/wp-content/uploads/2019/08/Qvist-Nuclear-and-Heat-Waves-August-2019-FINAL_.pdf	Taken into account. More peer reviewed literature has been added to the part on climate change impacts on thermal power plant operation. The literature now covers mitigation possibilities for thermal generation. The text has been revised accordingly, with a suggested reference added.	Daniel Westlén	Liberal party Swedish parliament	Sweden
45067	78	5	78	9	The impacts of climate change on thermal power plants may be insufficiently discussed in this section in comparison to those for renewable energy sources. The existing five lines of text in this section could benefit from such references as "A water-electricity nexus model to analyze thermoelectricity supply reliability under environmental regulations and economic penalties during drought events" (https://doi.org/10.1016/j.envsoft.2019.104514) and others.	Taken into account. The part of thermal power plants has been moved to 6.5.1.6. and expanded and more references are added, including the suggested reference.	Siir Kilkis	The Scientific and Technological Research Council of Turkey	Turkey
34401	78	6	78	9	CCUS should be replaced by CSS here. And the following sentence should be added after line 9: When external conditions lead to lower electricity production or even shut-down, CCU technologies could offer a useful alternative via power-to-X technologies (Farfan et al., 2019, Ram et al., 2019).Thanks to these technologies, excess renewable energy, generated when the demands for energy are low, could be stored and used when problems occur.	Taken into account. CCUS is removed from the text. Thermal power plant topic in general is moved to subsection 6.5.1.6, where CCS is mentioned. System integration aspects, including P2X, are presented in section 6.4.6.	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
6393	78	10	78	12	The statement should be supported with bibliographic references	Taken into account. References have been added, and the section has been revised	Sciacovelli Adriano	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
26977	78	10	78	22	The demand paragraph is not especific to the thermal power generation. It looks better if it is presented under another separate topic: "Impact on energy demand"	Taken into account. This part is now clarified. Electricity demand impacts are presented in 6.5.2.	Hossein Khajehpour	Energy Engineering Department, Sharif University of Technology	Iran
32469	78	10	78	22	In a warming world with a growing population and expanding middle-class, the demand for cooling is projected to rise substantially. Currently, there are 3.6 billion cooling appliances, which is projected to rise to 9.5 billion by 2050, though up to 14 billion would be required to provide adequate cooling for all. University of Birmingham (2018) A Cool World: Defining the Energy Conundrum of Cooling for All ("Considering per capita equipment penetrations at regional level, it becomes clear that 9.5 billion cooling appliances by 2050 will, on the current technology pathways, not be sufficient to deliver universal access to cooling, let alone meet the UN SDGs 2030 targets. Food and medicine loss in the supply chain will still be high; food poisoning from lack of cold chain and domestic temperature management will still be significant; farmers will lack market 'connectivity' or 'access'; hundreds of millions of people will not have safe, let alone comfortable, living or working environments; medical centres will not have temperature-controlled services for post-natal care, etc... By 2050, would require a total of 14 bn cooling appliances – an additional 4.5 bn appliances compared to the baseline forecast – or 4 times as many pieces of cooling equipment than are in use today."); Dreyfus G., et al. (2020) ASSESSMENT OF CLIMATE AND DEVELOPMENT BENEFITS OF EFFICIENT AND CLIMATE-FRIENDLY COOLING.	Taken into account. The increased need for cooling is now reported with more details in 6.5.2.	Durwood Zaelke	Institute for Governance & Sustainable Development	United States of America
32471	78	10	78	22	Reducing climate emissions from air conditioning while meeting cooling needs will require solutions that deliver cooling using less energy, i.e., more efficiently. Addition of cooling capacity in buildings is currently outpacing addition of solar generation capacity. Sachar et al. (2018) Solving the Global Cooling Challenge: How to Counter the Climate Threat from Room Air Conditioners. Rocky Mountain Institute, 10 ("A case in point is that last year (2017), our record year of solar growth, with 94 GW of total solar generation deployed globally, was eclipsed by the incremental load of new RACs added to the grid, estimated at approximately 100 GW."); International Energy Agency (2019) Perspectives for the Clean Energy Transition: The Critical Role of Buildings ("In fact, since 2000, the rate of electricity demand in buildings increased five-times faster than improvements in the carbon intensity of the power sector.").	Taken into account. The importance of efficiency in lowering cooling load is now noted in 6.5.2, with references. Cooling load is further presented in Chapter 5 and Section 6.4	Durwood Zaelke	Institute for Governance & Sustainable Development	United States of America
32473	78	10	78	22	For energy efficiency as it pertains to appliances and space cooling, the transition away from high-GWP HFCs (as mandated by the Kigali Amendment to the Montreal Protocol) provides an opportunity for revising the technologies to further improve energy efficiency. Dreyfus G., et al. (2020) ASSESSMENT OF CLIMATE AND DEVELOPMENT BENEFITS OF EFFICIENT AND CLIMATE-FRIENDLY COOLING; Sachar et al. (2018) Solving the Global Cooling Challenge: How to Counter the Climate Threat from Room Air Conditioners. Rocky Mountain Institute; Shah, N., Wei, M., Letschert, V. and Phadke, A. (2019). Benefits of Energy Efficient and Low-Global Warming Potential Refrigerant Cooling Equipment. U.S.A: Lawrence Berkeley National Laboratory; Shah N., et al. (2015) Benefits Of Leapfrogging To Superefficiency And Low Global Warming Potential Refrigerants In Air Conditioning, Ernest Orlando Lawrence Berkeley National Laboratory; IEA (2018) Future of Cooling; Sustainable Energy for All (2018) Chilling Prospects: Providing Sustainable Cooling for All; and Birmingham Energy Institute, University of Birmingham (2018) A Cool World: Defining the Energy Conundrum of Cooling for All.	Taken into account. The importance of efficiency in lowering cooling load is now noted in 6.5.2, with references.	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
32475	78	10	78	22	The increased energy demand that goes with increased demand for cooling often occurs during peak energy usage, especially during heat waves. Increased energy efficiency of cooling appliances can reduce how much energy needs to be generated and thus can limit additional growth in emissions from increased demand of cooling equipment. International Energy Agency (2018) Future of Cooling: Opportunities for Energy Efficient Air conditioning ("Space cooling can account for a large share of peak demand, placing further stress on the power system, especially during periods of extreme heat. Cooling demand typically jumps during a heatwave, placing greater demands on the power system, the reliability of which can be further undermined by hot equipment increasing the risk of outages. …For instance, the heatwave in France in August 2003, when temperatures rose to around 40°C across most of the country, boosted power needs by about 4 000 megawatts (MW), or around 10%, compared with normal peak summer electricity demand. In China, demand for cooling pushed overall electricity demand to record highs during the summer heatwave in 2017. In some places, such as Beijing on the 13 July 2017, more than 50% of the daily peak load was related to cooling."); Abel, D.W., Holloway, T., Martínez-Santos, J., Harkey, M., Tao, M., Kubes, C., Hayes S. (2019). Air Quality-Related Health Benefits of Energy Efficiency in the United States, Environmental Science & Technology 53 (7), 3987–3998 ("Increasing temperatures increase air conditioning use, this increases electricity demand, which in turn increases power plant emissions (Abel et al., 2017), and this may play a larger role in public health as air conditioning demand increases under a warmer climate (Abel et al., 2018.")."); Shah, N., Wei, M., Letschert, V. and Phadke, A. (2015). Benefits of Leapfrogging to Superefficiency and Low-Global Warming Potential Refrigerants in Room Air Conditioning. U.S.A.: Ernest Orlando Lawrence Berkeley National Laboratory ("We estimate that shifting the 2030 world stock of room air conditioners from the low efficiency technology using high-GWP refrigerants to higher efficiency technology and low-GWP refrigerants in parallel would save between 340-790 gigawatts (GW) of peak load globally, which is roughly equivalent to avoiding 680-1550 peak power plants of 500MW each."); Shah, N., Wei, M., Letschert, V. and Phadke, A. (2019). Benefits of Energy Efficient and Low-Global Warming Potential Refrigerant Cooling Equipment. U.S.A: Lawrence Berkeley National Laboratory.	Taken into account. The importance of cooling load efficiency, especially in reducing peak load is now noted in 6.5.2, with references.	Durwood Zaelke	Institute for Governance & Sustainable Development	United States of America
32795	78	10	78	22	The demand for cooling is projected to rise substantially. Currently, there are 3.6 billion cooling appliances, which is projected to rise to 9.5 billion by 2050, though up to 14 billion would be required to provide adequate cooling for all. University of Birmingham (2018) A Cool World: Defining the Energy Conundrum of Cooling for All ("Considering per capita equipment penetrations at regional level, it becomes clear that 9.5 billion cooling appliances by 2050 will, on the current technology pathways, not be sufficient to deliver universal access to cooling, let alone meet the UN SDGs 2030 targets. Food and medicine loss in the supply chain will still be high; food poisoning from lack of cold chain and domestic temperature management will still be significant; farmers will lack market 'connectivity' or 'access'; hundreds of millions of people will not have safe, let alone comfortable, living or working environments; medical centres will not have temperature-controlled services for post-natal care, etc... By 2050, would require a total of 14 bn cooling appliances – an additional 4.5 bn appliances compared to the baseline forecast – or 4 times as many pieces of cooling equipment than are in use today."); Dreyfus G., et al. (2020) ASSESSMENT OF CLIMATE AND DEVELOPMENT BENEFITS OF EFFICIENT AND CLIMATE-FRIENDLY COOLING.	Taken into account. The increased need for cooling is now reported with more details in 6.5.2. Cooling load is further presented in Chapter 5 and Section 6.4	Kristin Campbell	Institute for Governance & Sustainable Development	United States of America
32797	78	10	78	22	Reducing climate emissions from air conditioning while meeting cooling needs will require solutions that deliver cooling using less energy, i.e., more efficiently. Addition of cooling capacity in buildings is currently outpacing addition of solar generation capacity. Sachar et al. (2018) Solving the Global Cooling Challenge: How to Counter the Climate Threat from Room Air Conditioners. Rocky Mountain Institute, 10 ("A case in point is that last year (2017), our record year of solar growth, with 94 GW of total solar generation deployed globally, was eclipsed by the incremental load of new RACs added to the grid, estimated at approximately 100 GW."); International Energy Agency (2019) Perspectives for the Clean Energy Transition: The Critical Role of Buildings ("In fact, since 2000, the rate of electricity demand in buildings increased five-times faster than improvements in the carbon intensity of the power sector.").	Taken into account. The importance of efficiency in lowering cooling load is now noted in 6.5.2, with references. Cooling load is further presented in Chapter 5 and Section 6.4	Kristin Campbell	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
32799	78	10	78	22	For energy efficiency as it pertains to appliances and space cooling, the transition away from high-GWP HFCs provides an opportunity for revising the technologies to further improve energy efficiency. Dreyfus G., et al. (2020) ASSESSMENT OF CLIMATE AND DEVELOPMENT BENEFITS OF EFFICIENT AND CLIMATE-FRIENDLY COOLING; Sachar et al. (2018) Solving the Global Cooling Challenge: How to Counter the Climate Threat from Room Air Conditioners. Rocky Mountain Institute; Shah, N., Wei, M., Letschert, V. and Phadke, A. (2019). Benefits of Energy Efficient and Low-Global Warming Potential Refrigerant Cooling Equipment. U.S.A: Lawrence Berkeley National Laboratory; Shah N., et al. (2015) Benefits Of Leapfrogging To Superefficiency And Low Global Warming Potential Refrigerants In Air Conditioning, Ernest Orlando Lawrence Berkeley National Laboratory; IEA (2018) Future of Cooling; Sustainable Energy for All (2018) Chilling Prospects: Providing Sustainable Cooling for All; and Birmingham Energy Institute, University of Birmingham (2018) A Cool World: Defining the Energy Conundrum of Cooling for All.	Taken into account. The importance of efficiency in lowering cooling load is now noted in 6.5.2, with references.	Kristin Campbell	Institute for Governance & Sustainable Development	United States of America
32801	78	10	78	22	The increased energy demand that goes with increased demand for cooling often occurs during peak energy usage, especially during heat waves. Increased energy efficiency of cooling appliances can reduce how much energy needs to be generated and thus can limit additional growth in emissions from increased demand of cooling equipment. International Energy Agency (2018) Future of Cooling: Opportunities for Energy Efficient Air conditioning ("Space cooling can account for a large share of peak demand, placing further stress on the power system, especially during periods of extreme heat. Cooling demand typically jumps during a heatwave, placing greater demands on the power system, the reliability of which can be further undermined by hot equipment increasing the risk of outages. …For instance, the heatwave in France in August 2003, when temperatures rose to around 40°C across most of the country, boosted power needs by about 4 000 megawatts (MW), or around 10%, compared with normal peak summer electricity demand. In China, demand for cooling pushed overall electricity demand to record highs during the summer heatwave in 2017. In some places, such as Beijing on the 13 July 2017, more than 50% of the daily peak load was related to cooling."); Abel, D.W., Holloway, T., Martínez-Santos, J., Harkey, M., Tao, M., Kubes, C., Hayes S. (2019). Air Quality-Related Health Benefits of Energy Efficiency in the United States, Environmental Science & Technology 53 (7), 3987–3998 ("Increasing temperatures increase air conditioning use, this increases electricity demand, which in turn increases power plant emissions (Abel et al., 2017), and this may play a larger role in public health as air conditioning demand increases under a warmer climate (Abel et al., 2018.")."); Shah, N., Wei, M., Letschert, V. and Phadke, A. (2015). Benefits of Leapfrogging to Superefficiency and Low-Global Warming Potential Refrigerants in Room Air Conditioning. U.S.A.: Ernest Orlando Lawrence Berkeley National Laboratory ("We estimate that shifting the 2030 world stock of room air conditioners from the low efficiency technology using high-GWP refrigerants to higher efficiency technology and low-GWP refrigerants in parallel would save between 340-790 gigawatts (GW) of peak load globally, which is roughly equivalent to avoiding 680-1550 peak power plants of 500MW each."); Shah, N., Wei, M., Letschert, V. and Phadke, A. (2019). Benefits of Energy Efficient and Low-Global Warming Potential Refrigerant Cooling Equipment. U.S.A: Lawrence Berkeley National Laboratory.	Taken into account. The importance of cooling load efficiency, especially in reducing peak load is now noted in 6.5.2, with references. SAME AS COMMENT 32475 ABOVE	Kristin Campbell	Institute for Governance & Sustainable Development	United States of America
8993	78	11	78	12	The following sentence needs references: " Studies have consistently shown that heating demands will be lower and cooling demands will be higher." or rephrasing (I suggest not to mention "studies" that are not referenced).	Taken into account. References have been added, and the section has been revised	Jan Wohland	ETH Zürich	Switzerland
12785	78	24	78	31	The paper of Forzieri et al. (2018) shows the impact of 7 climate change driven natural hazards on critical infrastructures (including energy systems) in Europe. Those impacts are quantified and valued by sector, and period until 2100. Such estimations may be useful to discuss the general question of impacts on power systems. GEC Article: "Escalating impacts of climate extremes on critical infrastructures in Europe" https://www.sciencedirect.com/science/article/pii/S0959378017304077	Taken into account. The new reference has been added and text modified.	antoine leblois	INRA	France
42021	78	26			"… and network infrastructure, ALSO TO ICT SYSTEMS SUPPORTING THEM … "	Taken into account. The text has been modified.	Francisco Javier Hurtado Albir	European Patent Office	Germany
42023	78	27			" … of thermoelectric AND NUCLEAR generation"	Taken into account. The text has been modified.	Francisco Javier Hurtado Albir	European Patent Office	Germany
45381	78	28	78	29	Sea level rise's impact on power plants mentioned here but no data lin this section about % of vulnerable plants, etc. e.g. US source about sea level/ climate change risk for coastal generation capacity at risk "US power plant sites at risk of future sea-level rise" R Bierkandt1, M Auffhammer, and A Levermann, Environmental Research Letters, 22 December 2015, https://iopscience.iop.org/article/10.1088/1748-9326/10/12/124022	Taken into account. The new reference has been added and text modified.	Deborah Knuckey	Published energy journalist plus consultant for renewable energy development and finance companies through Kiterocket	United States of America

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
42027	78	32			6.5.3.1. In this section I suggest to add a further impact. SF6 (sulfur hexafluoride) has been used for many years to reduce the size of substations because of ist insulation properties. It has been also used in circuit breajkers. The consequence is always that the space needed for particular types of infrstructures integareted in electric power generation, transmission and distribution, is reduced. However, since SF6 is a GHG gas with a very high GWP (namely 23,500 for 100-year time horizon, according to the Fifth Assessment Report, AR5) and cannot be used for the original purpose	Rejected. Though SF6 is a significant potential vector for GHG emissions in the power sector, it is not in itself a threat to power system security as a natural hazard	Francisco Javier Hurtado Albir	European Patent Office	Germany
4479	78	37	78	44	Please also mention effects of high-wind speeds on solar PV and the need to build hurricane-proof solar PV in vulnerable areas such as the Caribbean	Taken into account. The text has been modified.	Leonardo Barreto	Austrian Energy Agency	Austria
13859	79	1	79	1	Wildfire in warmer climates may threat power lines, but power lines may also start fires. Regarding the power outages during wildfire events in California recently, disclaiming DSOs and TSOs from starting fires, are there some studies assessing the potential impact of that coupling climate change / power lines in starting wildfires ?	Rejected. Very little found in literature apart from that already cited	Alexandre Bizeul	International Energy Agency	France
6047	79	18	79	21	Repeating sentence for 'Snow, sleet, and blizzard faults can also be associated with overhead line faults when they coincide with high wind conditions (Murray and Bell 2014). '	editorial	SAIK PENG, CASEY NGO	R-SYNC TECHNICAL RESOURCES SDN. BHD.	Malaysia
18733	79	19	79	21	The sentence is repeated twice	editorial	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
39335	79	23	79	23	Flooding/ high discharge could also impact hydro power generation through increased sediment load, restriction in release of water from reservoir	Rejected - outside the scope of the section. We concentrate the assessment to the direct consequences of climate change on the energy system.	Suvra Majumdar	United Nations Development Programme	India
6049	79	27	79	29	This clause would be better placed under Thermal Effects instead of under Flooding - Heat can pose a risk to power system equipment. Referred to as solar heat faults (McColl et al 2012), they occur under conditions of high temperatures and low wind speeds and can be exacerbated by the urban heat island effect.	Taken into account. The text has been modified.	SAIK PENG, CASEY NGO	R-SYNC TECHNICAL RESOURCES SDN. BHD.	Malaysia
17021	79	27	79	29	"Heat can pose a risk to power system equipment...the urban heat island effect",I think this sentence seems to be inconsistent with the center ("Flooding presents as a threat to the transmission system ...") of this paragraph.I suggest that this paragraph be summarized into the next paragraph("Thermal effects...")	Taken into account. The text has been modified.	Qing YANG	Harvard University	China
42025	79	30			Under "thermal effects" it should be referred that high temperatures cause damage to insulators and have a negatve effect on ICT systems supporting them	Taken into account. The text has been modified.	Francisco Javier Hurtado Albir	European Patent Office	Germany
6051	79	31	79	36	Consider moving these clauses under new category i.e. Hydrology instead of under Thermal Effects - Droughts can affect the supply of hydropower and thermoelectric generation (Van Vliet et al. 2016b). Water availability affects hydro generation and cooling water availability affects thermoelectric (e.g., nuclear and fossil-fueled) generation (Koch et al 2014). (Van Vliet et al. 2016a) shows significant reduction in hydroelectric utilisation during acutely hot or drought years – with utilisation falling by 5.2% for hydroelectric and 3.8% of thermoelectric generation. This was primarily associated with water shortage.	Taken into account. The text has been modified.	SAIK PENG, CASEY NGO	R-SYNC TECHNICAL RESOURCES SDN. BHD.	Malaysia
42377	79	32	76	36	Hydrological cycle have large impact depending on its share and system type. The following summary may be useful to clarify the case. I recommend considering such clarification since this has implication for planning climate resilient system. As contribution of hydropower to power system with hydrocycle, power system would run into various challenge depending on local circumstances. For the hydro dominant Ethiopian system, hydro contribution was found to be 69 %, 90 % and 97 % of total annual demand on dry (low inflow), normal (moderate inflow) and high inflow years, respectively [1]. The consequence of these hydrological cycle is high volatility in cost of electricity, which was found to increase significantly on a dry year, and a potential shortage in energy supply. Depending on location, regulators and utilities should work to contain potential cost volatility and the risk of energy inadequacy. 1.A. A Demissie, A. A. Solomon, Power system sensitivity to extreme hydrological conditions as studied using an integrated reservoir and power system dispatch model, the case of Ethiopia. Applied Energy, 182 (2016) 442–463	Taken into account. The text has been modified.	Solomon Asfaw	LUT University	Finland
42375	79	40			I think "threating" should be "threatening"+D24:I26I23D23:I26D23:I26D22:I26D23:I26I23D23:I26D22:I26D21:I26	Editorial	Solomon Asfaw	LUT University	Finland
26979	79	42			Sandstorm can effectively cripple the power grid. Such issue happened in February 2017 in South-Western Iran. (https://www.alaraby.co.uk/english/news/2017/2/21/iran-blames-iraq-for-sandstorm-that-crippled-power-grid) As an adaptation option, the power grid must be burried under the ground so that the storms does not damage it. This is a very costly adaptation project. Such issue must be mentioned as a result of drought before ending the section 6.5.3.1. This is the suggested text: "Finally, the drought induced sandstorms may cripple the power grid, causing severe damage to the transmission and distribution grid."	Taken into account. The text has been modified.	Hossein Khajehpour	Energy Engineering Department, Sharif University of Technology	Iran

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45863	81	30	98	5	Roadmap for Carbon Recycling Technologies' was formulated mainly by academic experts and engineers in respective technology fields, with the cooperation of the Cabinet Office, Ministry of Education, Culture, Sports, Science and Technology, and Ministry of the Environment, for the purpose of specifying goals, technological challenges, and timeframes (directions to be aimed at for each phase) regarding Carbon Recycling technologies and having them shared widely among government officials, private companies, investors, researchers and other related parties in and outside Japan, thereby accelerating innovation.Refer to "https://www.meti.go.jp/press/2019/06/20190607002/20190607002-2.pdf"	Noted. We appreciate the reviewer's report suggestion, though it seems more appropriate for the section on CCUS earlier in the chapter.	MASANORI KOBAYASHI	New Energy and Industrial Technology Development Organization (NEDO)	Japan
9575	81	30			It would make a lot of sense to move this section forward in the chapter, so not first present exhaustive descriptions of sepoarate technologies first and then provide the context for them in policy rtelevant futures.	Noted. We thank the reviewer for their suggestion. Both orders for the chapter would make sense, and weighing the tradeoffs with each, we decided to keep the current chapter organization.	Tom Kram	PBL (Fellow)	Netherlands
34175	81	30			Maybe more emphasis on reducing energy consumption and of the possible obstacles https://www.sciencedirect.com/science/article/pii/S1364032115001471 [suggestion ENSEEIHT INP]	Thank you for this suggestion. We added a reference to this paper in the first paragraph of Section 6.2.2.	Antoine BONDUELLE	Climate Action Network France	France
46095	81	45	82	11	Box 6.13 here 100% RES systems should be listed also.	This box was removed and reference added to the definitions in another chapter of the report.	Neven Duic	University of Zagreb	Croatia
26595	81	45			Box 6.13 Add a new catergory 'Circular energy systems' those thermal systems that reuse energy discarding by other system such as cooling systems.	This box was removed and reference added to the definitions in another chapter of the report.	Peter North	Calorem Ltd, Imperial College (part-time PhD student)	United Kingdom (of Great Britain and Northern Ireland)
35609	81				section 6.6 seems to me to be the most substantive and significant section in the entire chapter. It tackles some of the key topics related to low carbon energy systems such as renewables integration. It is important to ensure that it is given adequate prominance in a chapter that is long on context and related societal factors. This section also contains many of the key findings/conclusions relevant to policy. I am not convinced that it is well-represented in the executive summary.	Noted. We appreciate the reviewer's suggestion. The executive summary will be revised, including more emphasis on material from Section 6.6.	Robert Gross	Imperial College and UKERC	United Kingdom (of Great Britain and Northern Ireland)
27949	82	1	82	11	Please add "100% renewable energy systems" and "100% clean, renewable energy systems" (the latter are also referred to as 100% wind-water-solar (WWS)" energy systems to the list of terms. Given that most laws worldwide and the Green New Deal are based on one of these two, and not the other terms defined, it is important that IPCC recognize these terms. The difference between 100% renewable and 100% clean, renewable is that the former allows dirty renewables that are combusted, such as biofuels, biomass, and bioenergy, and "renewable" fuels, whereas, the latter allows zero emissions because it allows only non-combusted clean, renewable energy (onshore/offshore wind, solar PV, CSP, solar heat, geothermal electricity and heat, hydroelectricity, tidal, and wave electricity) to power all energy (electricity, transportation, building heating/cooling, industry). The first reference for 100% clean, renewable WWS systems (and for the Green New Deal) is Jacobson, M.Z., and M.A. Delucchi, A path to sustainable energy by 2030, Scientific American, November 2009. See also 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 and 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.	This box was removed and reference added to the definitions in another chapter of the report.	Mark Jacobson	Stanford University	United States of America
45069	82	1	82	11	Additional definitions of future energy systems can be inserted from the scientific literature.	This box was removed and reference added to the definitions in another chapter of the report.	Siir Kilkis	The Scientific and Technological Research Council of Turkey	Turkey
8999	82	3	82	6	Two aspects of the definition of “climate-neutral energy systems” irritate me. First, calling it ‘climate-neutral’ rather than ‘carbon-neutral’ implies that you go beyond carbon and include other greenhouse gases such as methane and you also account for changes in atmospheric transmittivity, for example, due to aerosols. If this is the case, it is not sufficiently reflected in the given definition. It could easily be included by referring to, for example, CO2 equivalents. Second, I find the quotation marks ambiguous. If you use these categories to distinguish between energy systems that are (a) not net CO2 neutral themselves but could be part of a larger system that is net CO2 neutral and (b) systems that are net CO2 neutral themselves, I suggest to think about a different wording. Maybe this can be achieved by using Low carbon energy systems rather than climate neutral energy systems?	This box was removed and reference added to the definitions in another chapter of the report.	Jan Wohland	ETH Zürich	Switzerland
37409	82	3	82	6	Please provide explicit references to where the term 'climate neutral' has been used in the scientific domain. As described in the subsequent text, it is an ill defined term that can lead to any potential energy system configuration and thus has no particular relevance when discussing explicit energy system configurations.	This box was removed and reference added to the definitions in another chapter of the report.	Michiel Schaeffer	Climate Analytics	Netherlands
1243	82	3	82	8	State the difference between climate-neutral and carbon-neutral energy systems.	This box was removed and reference added to the definitions in another chapter of the report.	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
44607	82	3	83	6	I'm getting that the energy sector doesn't have to be at net zero if the whole economy is at net zero (in most scenarios, it seems to be below zero, and that's important to highlight). But I am a) confused why in that case you still apply the neutrality characterisation to the energy system - because what's neutral here is the whole economy, and b) I don't understand why it's called "climate-neutral" when it is still only about CO2, and c) climate-neutral is a problematic term, often used by politicians, companies and media when they in fact talk about GHG neutrality (e.g., in the EU's new long-term vision)	We revised the language in this section and use "carbon-netural" throughout (acknowledging that others may have different definitions in mind).	Oliver Geden	German Institute for International and Security Affairs	Germany
26223	82	3			The definitions of climate neutral and carbon neutral systems are confusing and not intuitive. Please rename them if possible	We revised the language in this section and use "carbon-netural" throughout (acknowledging that others may have different definitions in mind).	Sara Budinis	International Energy Agency	France
6395	82	4	82	4	It is unclear what 'Energy emission' means. Is it actually carbon emissions?	This box was removed and reference added to the definitions in another chapter of the report.	Sciacovelli Adriano	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
1241	82	5			Write the full-form of CDR	We changed "CDR" to "carbon removal".	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
32803	82	12	82	20	Because SLCPs are co-emitted with CO2 in energy production, transportation, and industry, CO2 mitigation measures will also reduce co-emitted non-CO2 climate forcers. CO2-targeted policies can mitigate 70% of methane emissions and 30% of black carbon emissions. SLCP-targeted measures—like reducing methane from the agricultural sector and HFCs from cooling needs—are necessary for maximum benefit. Allen M., et al. (2018) TECHNICAL SUMMARY, in IPCC (2018) GLOBAL WARMING OF 1.5 ºC, 33–34; Shoemaker J. K., et al. (2013) What Role for Short-Lived Climate Pollutants in Mitigation Policy?, SCIENCE 342:1323–1324; and Rogelj J., et al. (2018) CHAPTER 2: MITIGATION PATHWAYS COMPATIBLE WITH 1.5 ºC IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT, in IPCC (2018) GLOBAL WARMING OF 1.5 ºC, 96; Xu Y. & Ramanathan V. (2017) Well below 2 °C: Mitigation strategies for avoiding dangerous to catastrophic climate changes, PROC. NAT'L. ACAD. SCI. 114(39):10315–10323.	Noted. The language and reference in this passage are consistent with the reviewer's comment, though space constraints do not allow us to go into greater detail.	Kristin Campbell	Institute for Governance & Sustainable Development	United States of America
37411	82	12	82	30	The first paragraph begins saying that 'climate neutral' systems are a useful starting point but then is directly contradicted by saying in the second paragraph that there is no common defition or 'precise description' of what such a system looks like. This is exactly because it is an ill-defined term that any energy system configuration could fit under given mitigation outside the system boundaries of the energy system. Unless there is a clear definition of what such energy systems are, please refrane from using the term in a scientific text.	We agree that the previous wording was too ambiguous. We clarified the terminology in this section and use "carbon-neutral" instead.	Michiel Schaeffer	Climate Analytics	Netherlands
44609	82	14	82	14	I'd say "in long-term planning documents" - but at least in national plans/targets, it is usually net-zero GHG, not CO2, which is different from what the IPCC SR15 has been communicating	We updated this sentence to "planning documents." As mentioned in the other comments, we clarified the language in this section and consistently use "carbon-neutral."	Oliver Geden	German Institute for International and Security Affairs	Germany
1247	82	16			Please include the definition of net anthropogenic GHG emissions. It is not clear how GHG emission has been calculated in this chapter.. Does it entail total cradle to grave GHG emission of each technology? If it is based on cradle to grave GHG emission, please include whether life cycle assessment has been used in this GHG calculation? If not, state details about the tools, methods used in GHG emission. All net-zero discussion of GHG emission is meaningless without defining the process of GHG emission calculation.	We include a working definition of emissions at the beginning of the sub-section. Note that we revised the language in the section to focus on "carbon-neutral" systems (acknowledging that others may have different definitions in mind, which we attempt to summarize briefly in the box).	A M Mabrur Ahmad Rashedi	Charles Darwin University	Australia
44611	82	17	82	17	again, it's usually GHGs if it is about the overall, economy-wide target (e.g. EU, UK. Sweden etc. - New Zealand is a little different, but more than CO2 only)	We updated the wording in this sentence to "economy-wide goal."	Oliver Geden	German Institute for International and Security Affairs	Germany
1245	82	20			Explain the term 'land sink assumptions'	In the interest of brevity, we keep the phrase "land sink assumptions" (which seems appropriately descriptive for many audiences) in this section.	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
32477	82	21	82	30	Given the strong evidence that BECCS is not able to deliver negative emissions, its use as an example here is misleading. See Anderson K. & Peters G. (2016) The trouble with negative emissions, SCIENCE 354:182–183. BECCS is not carbon negative in the near-term because bioenergy leaves a carbon deficit for several decades to a century—far longer than the window of a decade or two available for slowing feedbacks and avoiding crashing through the 1.5C guardrail. See, e.g., IPCC AR5 WG III (2014) 11.13.4 GHG emission estimates of bioenergy production systems ("The combustion of biomass generates gross GHG emissions roughly equivalent to the combustion of fossil fuels. If bioenergy production is to generate a net reduction in emissions, it must do so by offsetting those emissions through increased net carbon uptake of biota and soils…Hence, the total climate forcing of bioenergy depends on feedstock, site-specific climate and ecosystems, management conditions, production pathways, end use, and on the interdependencies with energy and land markets…For example, in the specific case of existing forests that may continue to grow if not used for bioenergy, some studies employing counterfactual baselines show that forest bioenergy systems can temporarily have higher cumulative CO2 emissions than a fossil reference system (for a time period ranging from a few decades up to several centuries"). Subsequent analysis since AR5 further strengthens the case that bioenergy is not carbon neutral in the critical next decade or two. Danielle Venton, Core Concept: Can bioenergy with carbon capture and storage make an impact?, PNAS (2016); 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.	These paragraphs describe different CDR options and include citations with greater detail on the relative strengths and shortcomings of each. We also reference a multi-model study of biomass use under different decarbonization scenarios, which highlights the context- and region-specific impacts of bioenergy use for different applications and substitute technologies/fuel pathways.	Durwood Zaelke	Institute for Governance & Sustainable Development	United States of America
32477					comment continued: 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."). In addition, the CCS part of BECCS has not been demonstrated at scale or at acceptable cost, nor has it won over the support it would need from the public. See Gregory Nemet et al., Negative emissions—Part 3: Innovation and upscaling, Environ. Res. Lett. (May 2018); European Academies Science Advisory Council, Negative emission technologies: What role in meeting Paris Agreement targets? (Feb 2018) ("CCS plans in Europe have been shelved so that whatever experience is being gained globally is outside Europe. The loss in momentum in implementing CCS technologies not only has serious implications for mitigation pathways, but also one of the most commonly cited NETs [negative emissions technologies] (BECCS) assumes the availability of cost effective 'off-the shelf' CCS, while another (direct air capture) relies on the widespread availability of CO2 storage. At present, economic incentives for deploying CCS are inadequate (whether through the very low carbon price or targeted government support), while those for NET development are lacking."); Andersen & Peters, The Trouble with Negative Emissions, Science (Oct 2016). One study estimates that current rate of increase in CCS is 100 times lower than needed to meet the 2C target. See Haszeldine et al. (April 2018), Negative emissions technologies and carbon capture and storage to achieve the Paris Agreement commitments, Philosophical Transactions of the Royal Society. Thus, BECCS should not be presented as a viable CDR strategy.		Durwood Zaelke	Institute for Governance & Sustainable Development	United States of America
44613	82	21	83	16	I think the assumption that the energy sector (led by the power sector) is often net negative at the point of economy-wide net zero is very helpful, since many policymakers and even researchers (those beyond the modelling communities) ignore this. But again, it is unclear why you are using "climate-neutral" in this particular way. And good that you mention non-CO2 in the energy sector (fossil methane?) but you should indicate where in the report this is being dealt with (if it isn't, I guess you should do it, or at least indicate how big this problem is)	Good point. We added a sentence before the figure to make this point.	Oliver Geden	German Institute for International and Security Affairs	Germany
9003	82	25	82	30	You mention Direct Air Capture both as an important energy users and as a method that could be deployed outside the energy system. I believe the latter is wrong as DAC needs electricity to run and thus can not be deployed outside the energy system.	We clarified in this sentence that we are contrasting CDR methods that provide energy services (e.g., BECCS) with those that do not (e.g., DAC).	Jan Wohland	ETH Zürich	Switzerland
102	82	26	82	26	"be deployed within our outside of the energy sector (), although many CDR options" should be edited for clarity	We re-wrote this sentence.	Govindasamy Bala	Indian Institute of Science	India
9001	82	26	82	26	empty paranthesis ()	We removed the empty parentheses (and referenced Figure 6-33).	Jan Wohland	ETH Zürich	Switzerland
18735	82	26	82	26	be deployed within our outside of the energy sector ()' - should 'our' be 'or'? Should there be a reference in the brackets?	We re-wrote this sentence for clarity and to fix the reference issue.	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
20781	82	26			empty "()"	We fixed this empty reference.	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	China

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26239	82	26			()	We fixed this empty reference.	Sara Budinis	International Energy Agency	France
44615	83	1	83	1	Is this all for the same target level/scenario category?	We refined the caption to emphasize that we are including scenarios that reach net-zero total CO2 emissions.	Oliver Geden	German Institute for International and Security Affairs	Germany
9009	83	1	83	5	I suggest to make the caption more specific for ease of interpretation. In particular the last sentence could read “Points represent different models and subplots show different scenarios. The negative emission rates from energy CDR in the different scenarios are given In the subtitles are also color-coded.”	We refined the caption for this figure to be more descriptive.	Jan Wohland	ETH Zürich	Switzerland
20627	83	1	83	5	This figure seems like it could be very informative, but it isnt clear what it shows. What do the labels above each panel (i.e. "X-Y GtCO2/yr") refer to? Given that they are colour coded, according to the caption they should show the "amount of energy CDR", but that can't be since the unit is GtCO2/yr. Also the caption state that "all years" are shown. Really? Does that make sense? It seems that showing all years would only make sense if the pathway was shown. Perhaps limit to 2020, 2050 and 2100, with the separate years clearly indicated.	We refined the caption for this figure to be more descriptive.	Vassilis Daioglou	Copernicus Institute of Sustainable Development	Netherlands
9005	83	6	83	8	I suggest to remove “/or” as it does not contain any additional information and might be confusing. In the everyday usage of “or”, it implies that one has to choose between two options. This is not the case here as CDR that leads to net negative emissions in the energy sector also allows to offset remaining emissions from other sector.	We changed the wording to "and" in this sentence.	Jan Wohland	ETH Zürich	Switzerland
27951	83	7	83	11	IPCC states, "Types of climate-neutral energy systems are still speculative and have not been clearly explicated in country-specific pledges or in the systems modeling literature. Reports associated with net-zero economy-wide targets for countries and subnational entities typically do not provide detailed roadmaps or modeling but discuss high-level guiding principles for the transition toward climate-neutral energy systems." This statement is really not true. Here are three papers with specific plans for 143 countries or 139 countries to go to 100% clean, renewable energy among all energy sectors while keeping the grid stable and quantifying costs: 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. https://web.stanford.edu/group/efmh/jacobson/Articles/I/WWS-50-USState-plans.html and 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, https://doi.org/10.1016/j.renene.2018.02.009, https://web.stanford.edu/group/efmh/jacobson/Articles/I/CombiningRenew/WorldGridIntegration.pdf; 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, https://web.stanford.edu/group/efmh/jacobson/Articles/I/WWS-50-USState-plans.html	We expanded this subsection to convey the literature and potential gaps more clearly.	Mark Jacobson	Stanford University	United States of America
16467	83	17	106	6	I mainly read section 6.6.2 and 6.7.1. Although the texts are very readable, the two sections seem a bit 'weak' to me. A serious problem is that we simply present the conclusions of literature without providing sufficient supporting data, figure or table. Can we try to appropriately use more numbers or indicators? For instance, when discussing the transition strategies of electricity production, we could highlight the phasing-out time of conventional coal-fired power plants (I know Leon Clarke did some works on this topic) and the 2050 share of low-carbon generations; when discussing the electrification of end uses, we could present the electrification rate of the industry, building and transport sectors in 2050. Overall, what I intend to comment is that we should appropriately highlight some numbers rather than simply tell 'common knowledge'.	We appreciate the reviewer's suggestion. We attempted to add references and quantitative information to the chapter in this revision, though space constraints meant that we often had to use literature references to provide more detailed roadmaps.	Xunzhang Pan	School of Economics and Management, China University of Petroleum, Beijing 102249, China	China
37413	83	18	85	16	The usage of the terms 'climate neutral' and 'carbon neutral' are overlapping throughout the entirety of this section. p83l18 starts with 'carbon', p84-l7 switches to 'climate', and p84-l16 switches back to 'carbon'. As described already in section 6.6.1, the term 'climate neutral' is rife with uncertainty should simply be scrapped. This is already stated on p83l10-11: 'we will focus on carbon-neutral energy systems'.	We revised the language in this section and use "carbon-netural" throughout (acknowledging that others may have different definitions in mind).	Michiel Schaeffer	Climate Analytics	Netherlands

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27953	83	22	83	24	IPCC states, "Literature that takes a more granular view is more limited (e.g.,(Davis et al. 2018)), although there is an increasingly abundant literature on particular aspects of potential carbon neutral energy systems, most notably decarbonized electricity systems." However, very specific 100% all-sector (electricity, transportation, building heating/cooling, industry, agriculture/forestry/fishing, the military) plans have been developed for 143 and 139 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. https://web.stanford.edu/group/efmh/jacobson/Articles/I/WWS-50-USState-plans.html and 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, https://doi.org/10.1016/j.renene.2018.02.009, https://web.stanford.edu/group/efmh/jacobson/Articles/I/CombiningRenew/WorldGridIntegration.pdf; 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, https://web.stanford.edu/group/efmh/jacobson/Articles/I/WWS-50-USState-plans.html	We expanded this subsection to convey the literature and potential gaps more clearly.	Mark Jacobson	Stanford University	United States of America
829	83	42	83	45	add more references regarding thermal resilience, passive survivability, and similar topics addressed in the resilience, continuity of operations and climate change adapation literature.	Thank you for your suggestions. We wish we had enough space in this section to delve into more issues in greater depth (including those that you mention), but to meet the word count, we had to be selective about what to devote coverage to.	Ann Kosmal	U.S. General Services Administration	United States of America
20629	84	1	84	3	A paper currently under review also highlights they key aspects which can lead to a carbon-neutral energy system, particularly through the use of bioenergy. Bioenergy is particularly interesting because it can play multiple roles in the energy system (providing liquid fuels, gasseous fuels, heat, electricity, and CDR). This paper highlights the importance of CDR, projections of energy demand across different sectors, system inertia, and resource availability. The paper compares the results across a number of IAMs for harmonised scenarios meeting strict climate targets. DAIOGLOU, V., ROSE, S., BAUER, N., KITOUS, A., MURATORI, M., SANO, F., FUJIMORI, S., GIDDEN, M., KATO, E., KERAMIDAS, K., KLEIN, D., LEBLANC, F., TSUTSUI, J., WISE, M. & VAN VUUREN, D. in review. Bioenergy technologies and climate change mitigation pathways: Results from the EMF33 study. Climatic Change.	We appricate the reviewer's suggestion and added references to the EMF 33 study in the chapter.	Vassilis Daioglou	Copernicus Institute of Sustainable Development	Netherlands
31501	84	7	84	8	Again, I'm missing P2X here and in the following sections! Furthermore, I have seen already some climate-neutral scenarios. These exist only on the paper, but they are not speculative. I would like to replace the word "speculative" by something more certain like "are existing only on paper".	We added references to this section and also added more material about power-to-X pathways in other sections. We also changed the language here to add "in modeling studies."	Patrick Jochem	German Aerospace Center (DLR)	Germany
45071	84	7	84	8	Referral to "systems modeling literature" for climate-neutral energy systems can be made more consistent with the scientific literature based on support from such reviews as "Status and perspectives on 100% renewable energy systems" in Energy (2019) that is available at <https://doi.org/10.1016/j.energy.2019.03.092> as well as related articles, including but not limited to <https://doi.org/10.1016/j.rser.2018.11.038> and others.	We revised the language in this section to include additional reference and to better convey the literature gaps.	Siir Kilkis	The Scientific and Technological Research Council of Turkey	Turkey
44617	84	7	84	11	Some literature: high-level, quasi-official documents like the "Net Zero" study by the UK Climate Change Committee or the In-Depth Analysis accompanying the EU Commission's draft Long-Term Strategy). There's at least one peer reviewed study from the EU Commission's modelling team https://www.sciencedirect.com/science/article/abs/pii/S0301421519305476	We included this reference in the updated passage.	Oliver Geden	German Institute for International and Security Affairs	Germany
4481	84	7	84	15	Zero Energy Communities and Zero Energy Districts, which combine highly energy efficient buildings and local consumption of low carbon energy at the neighbordhood level, could also be mentioned	Noted. We are unfortunatley space constrained in this subsection and did not have enough room to include discussions of zero energy communities/districts.	Leonardo Barreto	Austrian Energy Agency	Austria

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9007	84	11	84	13	While I agree that the focus has generally been on individual sectors, combined investigations of many sectors (under the umbrella term sector coupling) have received increasing attention in the recent years. I suggest to acknowledge this in a sentence and maybe link to one key publication, such as Brown et al. (2018). Reference Brown, T., Schlachtberger, D., Kies, A., Schramm, S. & Greiner, M. Synergies of sector coupling and transmission reinforcement in a cost-optimised, highly renewable European energy system. Energy 160, 720–739 (2018).	We added a few references to this paragraph including to the Brown, et al. (2018) paper.	Jan Wohland	ETH Zürich	Switzerland
39199	84	16	84	16	The line "The literature on carbon-neutral energy systems is limited." ignores the wide literature on cross-sectoral studies with high penetration of renewable energy, see for example the reviews Brown et al https://doi.org/10.1016/j.energy.2019.03.092 and Hansen et al https://doi.org/10.1016/j.energy.2019.03.092	We added a few references to this paragraph including to the Brown, et al. (2018) paper.	Tom Brown	Karlsruhe Institute of Technology	Germany
20401	84	16	84	24	there is a broad literature basis available for carbon-neutral systems! The entire paragraph requires major revision. Latest perspectives on 100% renewables (which is carbon-neutral) provide links to 180 articles, most from last 10 years: https://www.sciencedirect.com/science/article/pii/S0360544219304967 - the existing literature covers a broad spectrum from power sector analyses to all-sector analyses; this enormous base of insights and literature has to be reflected in this paragraph	We updated the wording in this section to more clearly convey the literature gap.	Christian Breyer	LUT University	Finland
37415	84	16	84	24	overview para on literature on carbon neutral energy systems misses out completely on the important and growing body of literature showing feasibility of 100% RE based energy systems at global, regional, national level, and the increasing technological advances including demand side management, flexibiility, smart grids etc to achieve this.	We discuss this subset of the literature later in the section. We also added text to Section 6.6.2 to better describe the modeling gap.	Michiel Schaeffer	Climate Analytics	Netherlands
20403	84	25	85	3	the most important archetype is full missing! 100% renewable systems, as shown for 180 articles in Hansen at al. (https://www.sciencedirect.com/science/article/pii/S0360544219304967)	Taken into Account. The archetypes are taken from the illustrative pathways for this report, and we include one that is predominantly renewable energy along with decreasing demand.	Christian Breyer	LUT University	Finland
27955	84	26	84	26	IPCC states, "The possible configurations of carbon-neutral energy systems are limitless." This statement is not true as claimed. CCS, CDR, nuclear cannot help in solving the climate problem in 10 years, and we need an 80% transition in 10 years, and there is no evidence they will help after that. For example, the most recent review of the literature, Sekera, J., and A. Lichtenberger, The carbon capture conundrum: Public need versus private gain, A public policy perspective on carbon dioxide capture, 2020, https://drive.google.com/file/d/1K-BIULOUtfSs5LVCS9ONaDzq7jeFmO-b/view concludes (1) many scientific studies pass carbon removal methods off as "climate mitigation" when in reality the methods in play today increase CO2 and (2) laws subsidizing carbon capture and direct air capture increase CO2. This same result was found in 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. We respectfully disagree. Most, but not all, studies of net-zero systems include some degree of CDR. Both BECCS and DAC are integrated into the energy system, to different degrees. At the same time, it is also true that there is some ambiguity in the definition of net-zero energy systems, in that some CDR will take place out of the energy system, for example, through afforestation. This issue will be revisted in the final draft. In addition, it should be noted that we now have a box explicitly on 100% renewable electriciy and energy systems.	Mark Jacobson	Stanford University	United States of America
17069	84	35	84	36	It occurs to me that the combination of high renewables and low energy per capita energy demand rather reflects modelers' choice than inherent characteristics of energy systems.	Taken into Account. The archetypes are taken from the literature, but no comment is made about which is more less likely.	Kornelis Blok	Delft University of Technology	Netherlands
37417	84	35	84	36	this needs to include options for 100% RE and no CDR at least for carbon neutral (CDR would then turn this into carbon negative)	Taken into Account. The archetypes are taken from the illustrative pathways for this report, and we include one that is predominantly renewable energy along with decreasing demand.	Michiel Schaeffer	Climate Analytics	Netherlands
20631	85	5	85	15	Why is this box "Carbon Neutral" and not "Climate Neutral"? Perhaps the differences between these two should be highlighted? In this context, while I agree with the current contents of this box, when it is further expanded I think that the "Use of carbon dioxide removal" should be stated as a "strong maybe" characteristic. There are scenarios which reach the 1.5C target without the use of CDR (excluding AFOLU), however they require massive improvements elsewhere, especially concerning efficiency. Thus, given the fact that CDR, especially BECCS, is not highly regarded in social and (some) academic circles, the tradeoffs and what a CDR-free system would look like should be clearly highlighted.	Taken into account. We have moved to the net-zero language as agreed on for this report.	Vassilis Daioglou	Copernicus Institute of Sustainable Development	Netherlands
26597	85	5			Box 6.15 add bullet point 'reuse of energy'.	The "reuse of energy" is discussed under the heading of "More efficient use of energy than today" in Section 6.6.2.5.	Peter North	Calorem Ltd, Imperial College (part-time PhD student)	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
27957	85	6	85	15	IPCC states, "there are a number of characteristics of these systems that can be found across scenarios in the literature...Use of carbon dioxide removal (CDR) technologies" This statement does not appear to be accurate. Not one of these 47 papers that simulates 100% renewable energy systems includes CDR technologies http://web.stanford.edu/group/efmh/jacobson/Articles/I/CombiningRenew/100PercentPaperAbstracts.pdf and 100% renewable energy systems can attain 350 ppmv CO2 by 2100 if 80% of energy is transitioned to clean, renewable energy by 2030 and 100% by no later than 2050. http://web.stanford.edu/group/efmh/jacobson/Articles/I/CountryGraphs/CO2ChangesWithWWS.pdf	Rejected. We respectfully disagree. Most, but not all, studies of net-zero systems include some degree of CDR. Both BECCS and DAC are integrated into the energy system, to different degrees. At the same time, it is also true that there is some ambiguity in the definition of net-zero energy systems, in that some CDR will take place out of the energy system, for example, through afforestation. This issue will be revisted in the final draft. In addition, it should be noted that we now have a box explicitly on 100% renewable electriciy and energy systems.	Mark Jacobson	Stanford University	United States of America
31503	85	17	85	25	One of the main challenges is still “how can we convince ALL countries to keep the fossil fuels untouched in their grounds”. McGlade, Christophe, and Paul Ekins. "The geographical distribution of fossil fuels unused when limiting global warming to 2 C." Nature 517.7533 (2015): 187-190. https://doi.org/10.1038/nature14016	We have noted the challenge of "unused" fossil fuels in the revised section, including a reference to McGlade and Ekins.	Patrick Jochem	German Aerospace Center (DLR)	Germany
3009	85	18	85	19	The statement that "virtually all climate-related energy systems in the literature use far less fossil fuels than today" is rather quite strong and needs qualifications in a number of dimensions: 1- By what time in the future compared to today, 2- whether the climate-neutral energy sytem is defined at the economy level or global level. At economy level the statement may not be true but could be true at the global level, 3- is it "fossil fuels" or rather non-carbon-abated fossil fuels?, 4- countries endowments and national circumstances largely determines the evolution of economy-level energy systems.	The wording in the revised section has been updated to be more specific regarding timing and regional scope, including new references to published scenarios.	Mustafa Babiker	Aramco	Saudi Arabia
37419	85	18	85	20	WG3 FOD Ch4 states that the energy system must reach net zero (ie carbon-neutral) in order to reach 1.5C (pg3-35ln23) - which is inconsistent with the claim that energy systems must be 'climate neutral'. This term is inconsistent with other chapters and should simply not be used.	The definitions of net-zero, carbon-neutral, and climate-neutral have been clarified and streamlined in the revised text.	Michiel Schaeffer	Climate Analytics	Netherlands
37421	85	18	85	25	this para falls behind assessment of IPCC SR 15 in particular regarding robust result that fossil fuels need to be phased out and in particular coal	The wording in the revised section has been updated to be more specific regarding the trajectory of energy systems, including new references to published scenarios.	Michiel Schaeffer	Climate Analytics	Netherlands
34403	85	21	85	22	It should be: (e.g. CDR, CCS and CCU).	The revised section includes the possibility of carbon utilization in the list.	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
12403	85	22	85	25	At the same time reaching the Paris goal will be much more expencive without CCS (energy and industry sector)	The wording in the revised section has been updated to be more specific regarding the trajectory of energy systems, including their costs, with new references to published scenarios.	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
20523	85	22	85	25	no fossil fuel demand has been found in Ram et al. (http://energywatchgroup.org/wp-content/uploads/EWG_LUT_100RE_All_Sectors_Global_Report_2019.pdf), while the scenario had been highly cost attractive. Thus fossil fuels are not needed anymore in the energy system beyond 2050. This includes fossil oil, fossil coal and fossil gas. All remaining hydrocarbon demand for fuels can be supplied by CCU (mainly DACCU) and PtX, also shown in Ram et al.	The text as written admits of the possibility of no fossil fuel demand.	Christian Breyer	LUT University	Finland
31681	85	25	85	25	The last sentence is very evasive. On which assumptions is based the supposedly low coal demand ? Is it worldwide ? The use of coal is essentially concentrated in the countries that extract it. It is not a very exported resource. How can we ensure that those countries won’t use it for domestic usage even if the whole world asks them not to ? This guess is based on the fact that countries will respect the 2°C limit but some might want to go rogue and dig that coal. So even if the world market demand of coal is low, they can have a sufficient intern market to use it. And countries might want to pour subsidies in those mines. This market-thinking is dangerous as it does not allow to considered arbitrary decisions. The recent (March 2020) oil war shows that the energy sector is not a good candidate to market theory.	It is possible that countries with coal endowments may choose to extract the coal even if the related energy could be produced more cheaply by non-fossil sources, but we have not found literature pointing to such market failure. The revised text addresses the challenge of unburnable fossil resources.	Alan BURLOT	Commissariat à l'énergie atomique et aux énergies alternatives	France
25079	85	33	85	33	Delete "Indeed, such competition … sources of fuels."	The revised section has been rewritten to clarify how the relationship of negative emissions and residual emissions in published scenarios.	Eleni Kaditi	Organization of the Petroleum Exporting Countries (OPEC)	Austria
20405	85	35	85	37	key reference for this statement is missing, as shown in a comprehensive manner by Hansen et al. (https://www.sciencedirect.com/science/article/pii/S0360544219304967)	We added a reference to this paper later in the section.	Christian Breyer	LUT University	Finland

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
27959	85	35	85	37	IPCC states, "Because there are so many lower-cost options for producing zero-carbon electricity, decarbonized or net-negative-emissions electricity systems are robust characteristics of carbon-neutral energy systems." Please cite earlier work on a fully-electrified, zero combustion worldwide energy system: (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 and (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.	We appreciate your suggestion. 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.	Mark Jacobson	Stanford University	United States of America
20407	86	1	86	4	this statement is wrong. 100% renewable is also possible, so NO nuclear or fossil CCS is needed. This is clearly stated by Hansen et al. (https://www.sciencedirect.com/science/article/pii/S0360544219304967) for 180 articles, and by Breyer (https://www.sciencedirect.com/science/article/pii/B9780081028865000347) in an overview on the topic.	This sentence was modified to reflect that net-zero systems "could" include a range of technologies listed, rather than "will" entail a mix of technologies (since "optimal" mixes will vary by region and will be informed by a range of considerations).	Christian Breyer	LUT University	Finland
37423	86	1	86	12	this is a very biased characterisation of literature and technology development and potential for RE. It is wrong to claim that only thermal power provides dispatchable generation. Also renewables do (e.g. biomass, hydro, as well as variable re and storage with grid management/demand side management). this is way out of date. Also claiming 100% RE is not desirable is highly biased and not substnatiated. LArge body of literature showing feasibility and benefits of 100% RE at global, regional, natioanl, subnational level. The benefits of e.g. solar technology for remote regions, distributed energy in many regions can reduce need for grid transmission	We updated the first sentence to separately list variable renewables and dispatchable renewables. The second sentence was also rewritten to better reflect the literature.	Michiel Schaeffer	Climate Analytics	Netherlands
31505	86	1	87	48	On these pages there are many things already mentioned above. Shorten?	The renewable integration box is intended to stand by itself, hence there is some repetition with material elsewhere in Chapter 6.	Patrick Jochem	German Aerospace Center (DLR)	Germany
9011	86	2	86	3	There are dispatchable (large reservoir hydro, biomass, on daily timescales even concentrating solar power) and non-dispatchable renewables (wind, solar pv). It is really important to mention this basic fact here. Treating all renewables as non-dispatchable generators is not fair. Similarly, CCS is not a way to generate electricity and should consequently not be listed here. It could make sense to mention gas + CCS here.	This passage was updated to separately list variable renewables and dispatchable renewables. We also updated "CCS" to "CCS-equipped capacity."	Jan Wohland	ETH Zürich	Switzerland
27961	86	2	86	4	IPCC states, "These systems will entail a mix of renewables, dispatchable (“on demand”) low-carbon generation (e.g., nuclear, CCS), energy storage, transmission, and demand management (Bistline et al. 2018; Jenkins et al. 2018b; Luderer et al. 2017; Macdonald et al. 2016)." The authors of this chapter are ignoring entirely the 13 independent research groups who find that 100% renewable energy systems across some or all energy sectors are possible WITHOUT nuclear or CCS. http://web.stanford.edu/group/efmh/jacobson/Articles/I/CombiningRenew/100PercentPaperAbstracts.pdf. For example, 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. https://web.stanford.edu/group/efmh/jacobson/Articles/I/WWS-50-USState-plans.html find 100% clean, renewable energy systems across all energy sectors feasible at low cost in 143 countries of the world. Please clarify that future systems may consist of renewables, energy storage, transmission, and demand management WITHOUT including nuclear or CCS.	This sentence was modified to reflect that net-zero systems "could" include a range of technologies listed, rather than "will" entail a mix of technologies (since "optimal" mixes will vary by region and will be informed by a range of considerations).	Mark Jacobson	Stanford University	United States of America
34405	86	3	86	3	CCS does not allow to produce low carbon energy, it allows to capture and store the carbon of high carbon emission energy production. It should not be discussed at the same level as nuclear power as CCS does not produce power/energy. Please add in the sentence : "energy storage (e.g. CCU)"	We also updated "CCS" to "CCS-equipped capacity."	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
9013	86	4	86	6	“a larger portion on average than it does today” is a massive understatement. Given the huge decline in installation costs (e.g., IEA/IRENA, Creutzig 2017), a dominant contribution of variable renewables appears the most likely case. References: Creutzig, F. et al. The underestimated potential of solar energy to mitigate climate change. Nat Energy 2, 17140 (2017). IEA/IRENA: Perspectives for the Energy Transition, International Energy Agency/International Renewable Energy Agency, Tech. Rep., 2017.	We updated this sentence to better reflect the expected role of variable renewables in the literature, "Variable renewable energy will likely comprise large shares of many regional generation mixes..."	Jan Wohland	ETH Zürich	Switzerland

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
5653	86	4	86	8	The following recent reference provides additional evidence to support the notion that the costs of decabonizing the grid with renewable power increase significantly on the margin as 100% decarbonization is approached. Jayadev, G., Leibowicz, B.D., Kutanoglu, E., 2020. U.S. electricity infrastructure of the future: Generation and transmission pathways through 2050. Applied Energy 260, 114267.	We cite this analysis earlier in the paragraph.	Benjamin Leibowicz	The University of Texas at Austin	United States of America
20409	86	4	86	8	this statement is wrong, as shown by 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) since both show that the presenet system cost an be reduced in a 100% renewable energy system	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 Bogdanov, et al. (2019) paper does not conduct experiments where renewable shares are varied. Rather, it looks at a future 100% renewable mix (where other technologies are excluded from the choice set) and compares it with costs of a 2015 system. The paper does not examine whether lower-cost portfolios are available.	Christian Breyer	LUT University	Finland
42379	86	5	86	12	There are two problems in this section. First, it seems that unintentionally 100% RE is interpreted as a simple 100% variable renewable energy (VRE) system. Given the presence of diverse RE resources in several places around the globe and the possibility of inter-regional electricity trade, achieving 100% VRE may not be mandatory at most geographic locations. Thus, 100% RE could be 60% VRE for some locations and 80% VRE for others and may be 100% VRE for regions with less resource diversity. This could have been confirmed from several 100% RE papers in the literature. On the other hand, given the information I provided above in other comments, for most regions with diverse resource, storage requirement does not exceed daily average demand if system design and operation is optimized anticipating VRE. The storage required will also be diurnal type but its design can not follow existing tradition. Seasonal storage will be mandatory for systems that may have to go to more than 90% VRE. More importantly, I was evaluating the document based on the assertion in page 5 line 25-26 that states “that countries take other factors into consideration when choosing their transition path”. But I am puzzled to see that high VRE received poor attention based on arguments that are based on references that reflects one angle. First, it is true that cost is uncertain. Second, results in this area also depend on model type, technology type they assumed and the level of system optimality that they can achieve. Given these issues the impartiality of the report can be questioned when you evaluate it as a neutral person. Second, the references used to justify your arguments (that balancing cost increases with penetration, etc) are produced based on models that enforces traditional power system planning rules. At the same time, the technology diversity of the study is limited. Thus, their conclusion is not a surprise. If any one wants to understand the complexities of designing high VRE grid (not 100% VRE) should get some lessons by reading at least these three papers [1-3]. 1. Solomon A.A. Large scale photovoltaics and the future energy system requirement. AIMS Energy, 2019, 7(5):600–618 2. Solomon AA, Bogdanov D, Breyer C (2019) Curtailment-storage-penetration nexus in energy transition. Applied Energy 235:1351–1368 3. Solomon AA, Kammen DM, Callaway D (2014) The role of large-scale energy storage design and dispatch in	The language in this paragraph was revised to make a distinction between variable renewables and other renewables. We also appreciate the reviewer's paper suggestions. There are many more applicable papers than we have room to include, so we must be selective. The papers cited do not differ significantly from other papers referenced in its methods, scope, or findings to merit inclusion in this section.	Solomon Asfaw	LUT University	Finland

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
27963	86	7	86	8	IPCC states, "economic and operational challenges increase sharply as shares approach 100 percent (Bistline and Young 2019; Shaner et al. 2018; Bistline 2017; Gowrisankaran et al. 2016; Frew et al. 2016). This statement is contradicted by many of the 47 peer-reviewed studies among 13 independent research groups that find low-cost renewables with 100% renewable energy possible at low cost (http://web.stanford.edu/group/efmh/jacobson/Articles/I/CombiningRenew/100PercentPaperAbstracts.pdf). Specifically, for example, the following two papers find costs, averaged across all energy sectors, of a 100% clean, renewable Wind-Water-Solar (WWS) system in 143 and 139 countries, respectively, to be lower than BAU fuel costs: 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. https://web.stanford.edu/group/efmh/jacobson/Articles/I/WWS-50-USState-plans.html and 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, https://doi.org/10.1016/j.renene.2018.02.009, https://web.stanford.edu/group/efmh/jacobson/Articles/I/CombiningRenew/WorldGridIntegration.pdf . These papers, therefore, debunk the claims that costs "increase sharply." Please include these references to contradict this claim. The reasons why the citations such as Shaner et al., (2018) are erroneous are provide on Pages 457-458 of the Jacobson et al. One Earth, 2019 study cited above.	We appreciate the reviewer's suggestions. 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). If it weren't the case that costs/value change significantly as shares approach 100%, then multi-model comparisons would find all-renewables systems as least-cost solutions, but as the reviews in this section suggest, studies very rarely do unless they restrict the availability of technologies.	Mark Jacobson	Stanford University	United States of America
9015	86	8	86	10	This sentence (“There are… variability”) is unncessarily vague and could be falsely interpreted to mean that it is unclear if power system can handle, for example, 30% renewable generation while in reality there is absolute clarity that they can. To avoid this confusion, I suggest to rephrase like this: “There is evidence that national power systems can function reliably with substantial shares of variable renewable generation (e.g., Denmark, Germany). The strategies and technologies to accommodate even higher shares up to fully-renewable systems have been demonstrated in modeling studies (see Box 6.16). In real-world systems, nevertheless, additional challenges will emerge as exemplified by the rising importance of congestion management (Wohland et al., 2017).” References: Wohland, J., Reyers, M., Märker, C. & Witthaut, D. Natural wind variability triggered drop in German redispatch volume and costs from 2015 to 2016. PLoS ONE 13, e0190707 (2018).	We updated this paragraph to note the experience with real-world systems and to clarify the areas of debate in prospective modeled systems.	Jan Wohland	ETH Zürich	Switzerland
9017	86	19	86	36	Transmission and the reduction of renewable variability through optimized allocation are largely missing in this discussion. This does neither reflect their importance, nor the body of available literature. I suggest to include these aspects, for example, as follows: ll. 24 ff: “and business models (Gallo et al. 2016b). The need for energy storage can be substantially reduced through large-scale transmission (Rasmussen 2012, Rodriguez, 2013, Schlachtberger 2017) and optimized allocation of renewable generation (Grams, 2017, Santos-Alamillos, 2017).” References: Rasmussen, M. G., Andresen, G. B. & Greiner, M. Storage and balancing synergies in a fully or highly renewable pan-European power system. Energy Policy 51, 642–651 (2012). Rodríguez, R. A., Becker, S., Andresen, G. B., Heide, D. & Greiner, M. Transmission needs across a fully renewable European power system. Renewable Energy 63, 467–476 (2014). Schlachtberger, D. P., Brown, T., Schramm, S. & Greiner, M. The benefits of cooperation in a highly renewable European electricity network. Energy 134, 469–481 (2017). Grams, C. M., Beerli, R., Pfenninger, S., Staffell, I. & Wernli, H. Balancing Europe’s wind-power output through spatial deployment informed by weather regimes. Nature Clim Change 7, 557–562 (2017). Santos-Alamillos, F. J. et al. Exploring the meteorological potential for planning a high performance European electricity super-grid: optimal power capacity distribution among countries. Environ. Res. Lett. 12, 114030 (2017).	We added a sentence to this paragraph to highlight other renewable integration strategies (including transmission) that could interact with energy storage. This material is also discussed in the renewable integration box.	Jan Wohland	ETH Zürich	Switzerland
11997	86	22	86	24	Storing over longer period will typicly require a larger plant e.g. a hydropower dam and therefore influence the need for a grid over longer distances and with enough capasity. I think this also should be described here.	Noted. The references in this sentence describe possible long-duration energy storage technologies and their associated considerations.	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
9019	86	27	86	27	Suggest to also add the possibility of flexible DAC operation to use renewable excess electricity, thereby combing the challenges of negative emissions and renewable generation variability. Maybe like this: “asset utilization (Realmonte et al. 2019). Conversely, if DAC installation costs fell substantially, decentralized DAC units could be run flexibly to alleviate grid congestion and make efficient use of high renewable feed-in during favourable meteorological conditions (Wohland et al, 2018).” References: Wohland, J., Witthaut, D. & Schleussner, C.-F. Negative Emission Potential of Direct Air Capture Powered by Renewable Excess Electricity in Europe. Earth’s Future 6, 1380–1384 (2018).	We added a reference to the potential role of DAC in this paragraph in discussing complements and substitutes for energy storage.	Jan Wohland	ETH Zürich	Switzerland
20411	86	37	86	40	also the aviation and marine sector can be managed with Power-to-x/DACCU, as shown by Ram et al. (http://energywatchgroup.org/wp-content/uploads/EWG_LUT_100RE_All_Sectors_Global_Report_2019.pdf) and Horvath et al. (https://www.sciencedirect.com/science/article/pii/S0196890418302152) for the marine sector. Khalili et al. (https://www.mdpi.com/1996-1073/12/20/3870) provides a broad discussion and in sections 3.3 and 3.4 the high efficiency of directly and indirectly renewable electricity based solutions is presented	We added a sentence in this paragraph to explicitly mention power-to-X pathways and pointed the reader to the subsection that discusses these applications in greater detail.	Christian Breyer	LUT University	Finland
44785	86	40	86	41	”BECCS could displace other low- to zero-carbon options like wind, solar, and nuclear.” BECCS implies more use of bio-fuel, there are severe constraints there. So, although very important, it is not likely to displace other low- to zero carbon options, it should aim to displace the fossil options as a first step. The sentence needs to be explained.	We re-wrote this sentence to clarify that BECCS impacts on power system planning are context-dependent.	Daniel Westlén	Liberal party Swedish parliament	Sweden
34695	87	1	87	7	The need of an holistic approach for the 100% renewable mix is a consideration that should be pointed out (Kenneth Hansen, Christian Breyer, Henrik Lund,Status and perspectives on 100% renewable energy systems,Energy,Volume 175,2019,Pages 471-480,ISSN 0360-5442,https://doi.org/10.1016/j.energy.2019.03.092.)	We added a sentence at the end of the penultimate paragraph to point out how decarbonization strategies in other sectors may impact power sector planning and renewables integration. We also added a citation to the Hansen, et al. (2019) paper in this section.	Jordi Solé-Ollé	Spanish National Research Council (CSIC)	Spain
17071	87	1	88	18	A very important reference is missing here: Brown et al. 2018 Synergies of sector coupling and transmission extension in a cost-optimised, highly renewable European energy system. This is probably the one paper that carries out optimization across all flexibility options (grid expansion, demand response, short- and long-term storage).	A reference to Brown, et al. (2018) was added to this section.	Kornelis Blok	Delft University of Technology	Netherlands
17073	87	1	88	18	Also, the work of Breyer et al should be discussed here. Summary report here: http://energywatchgroup.org/wp-content/uploads/EWG_LUT_100RE_All_Sectors_Global_Report_2019.pdf. Abundant references, for many countries, in Appendix.	We appreciate your suggestion. 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 merit inclusion in this section.	Kornelis Blok	Delft University of Technology	Netherlands
17075	87	1	88	18	There is overlap of Box 16.6 with section 6.4.6.2. Maybe integrate?	While there is a little overlap between these sections (so that each can stand alone), the two focus on separate issues: One on integration of high renewables (in the box) and the other on the role of low-carbon electricity in carbon-neutral energy systems (in the section).	Kornelis Blok	Delft University of Technology	Netherlands
46097	87	1	88	18	Box 6.16 missing references on 100% RES systems, missing power to heat and other power-to-X options	We expanded the final bullet in the list to include sector coupling and references to power-to-X studies.	Neven Duic	University of Zagreb	Croatia
15147	87	3	87	3	Highly recommend including not only the proportion of solar and wind in creating carbon-neutral energy systems. But also look broader at the power system, including other renewables: hydropower. To modify the line and enlarge to hydropower the following line: 'As countries consider potential future carbon-neutral energy systems, an important question that arises is the proportion of wind and solar energy that can be included in the power system'	We acknowledge the potential role for other renewable technologies in the box and in the surrounding sections. However, we call out wind and solar specifically here given their unique characteristics that make integration challenges more salient and given cost reductions that increase their expected roles in future energy systems.	Aleksandr Kraevoy	UC RUSAL	Russian Federation

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
9021	87	5	87	10	These sentences mix renewable generation variability and forecast uncertainty in a way that I find confusing. I suggest to point out more clearly that renewable generation variability stems from climate variability which is an inherent statistical property of the complex climate system. Forecast uncertainty, in contrast, is due to the fact that numerical weather prediction is a starting-value problem with uncertain starting conditions and imperfect model representations. I would rephrase along these lines: “generation (Cole et al. 2017). Improved representation of climate variability in energy models allows to constrain renewable generation variability and considerable progress has been made in this field (e.g., Pfenninger & Staffell 2016, Bloomfield et al. 2016, Pryor 2018) while new questions arise on multidecadal time scales (Wohland et al. 2019). Forecast errors can impact power plant...” References Pfenninger, S. & Staffell, I. Long-term patterns of European PV output using 30 years of validated hourly reanalysis and satellite data. Energy 114, 1251–1265 (2016). Bloomfield, H. C., Brayshaw, D. J., Shaffrey, L. C., Coker, P. J. & Thornton, H. E. Quantifying the increasing sensitivity of power systems to climate variability. Environ. Res. Lett. 11, 124025 (2016). Pryor, S. C., Shepherd, T. J. & Barthelmie, R. J. Interannual variability of wind climates and wind turbine annual energy production. Wind Energ. Sci. 3, 651–665 (2018). Wohland, J., Omrani, N. E., Keenlyside, N. & Witthaut, D. Significant multidecadal variability in German wind energy generation. Wind Energ. Sci. 4, 515–526 (2019).	We agree that these sentences could be expanded to provide additional detail about climate variability and forecast uncertainty. However, our goal here is not to provide a comprehensive overview of these areas but instead to succinctly introduce the topic with a plain English description (and include a reference for interested readers to learn more).	Jan Wohland	ETH Zürich	Switzerland
27965	87	16	87	17	IPCC states, "studies illustrate the technical feasibility of using renewables to meet hourly electricity demand under a range of conditions (Zappa et al. 2019; Cochran et al. 2014b)." Please cite a greater number of the 47 papers, including earlier studies, on this subject listed here http://web.stanford.edu/group/efmh/jacobson/Articles/I/CombiningRenew/100PercentPaperAbstracts.pdf	We added a citation to a literature review (Hansen, et al., 2019) that includes many of the papers the reviewer cites.	Mark Jacobson	Stanford University	United States of America
12021	87	18	87	41	We appreciate this information about balancing options, however some of the bullets could benefit from more concrete description.	We appreciate the suggestion. The box is space-constrained, and to keep it brief, we use literature citations to provide additional information for interested readers.	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
20417	87	18	87	41	the entire set of flexibility options being available to integrate renewables and also reduce total system cost is presented by Child et al. (https://www.sciencedirect.com/science/article/pii/S136403211830176X)	We appreciate the suggested citation. There are many more applicable papers than we have room to include, so we must be selective. We added to the text before the bulleted list to acknowledge that there are additional options.	Christian Breyer	LUT University	Finland
42381	87	18	87	41	In an optimally designed system, curtailment is also balancing mechanism that carries economic and technical benefit. Please read [1] and modify the discussion. 1. Solomon AA, Bogdanov D, Breyer C (2019) Curtailment-storage-penetration nexus in energy transition. Applied Energy 235:1351–1368	The box is limited in space, so we focus on a few integration options and provide references for readers to learn more about these and additional balancing strategies. We added to the text before the bulleted list to acknowledge that there are additional options.	Solomon Asfaw	LUT University	Finland
34407	87	19	86	26	Addition: Energy storage technologies like batteries, pumped hydro, hydrogen and CCU can provide a range of system services (REFERENCE ADDED:CONCAWE, 2019: A look into the role of e-fuels in the transport system in Europe (2030–2050) (literature review), CONCAWE./ IEAGHG, 2019b: Exploring Clean Energy Pathways: the role of energy storage, International Energy Agency.)	We added a sentence in the paragraph following the bulleted list to point out how balancing options may also be "prioritized based on other systems services they provide."	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
38025	87	19	87	19	Add "storage hydropower" between"batteries," and "pumped hydro" in the sentence. Storage hydropower provides renewable energy storage	We are not enumerating a complete list of all energy storage technologies but instead are highlighting a few options and providing citations for interested readers to learn more.	Atle Harby	SINTEF Energy Research	Norway
20413	87	19	87	26	Bogdanov et al. (https://www.nature.com/articles/s41467-019-08855-1) and Solomon et al. (https://www.sciencedirect.com/science/article/pii/S0306261918317756) show how storage is used for an optimised renewables integration up to 100% renewables, as least cost solution	We appreciate your suggestion. 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 merit inclusion in this section.	Christian Breyer	LUT University	Finland
26599	87	19			This section is exclusively electricity storage. However there is a role for thermal storage in connection with district heating and the use of heat pumps. The cost of thermal storage is around 1000 times less that battery storage for the same capacity.	We are not enumerating a complete list of all energy storage technologies but instead are highlighting a few options and providing citations for interested readers to learn more.	Peter North	Calorem Ltd, Imperial College (part-time PhD student)	United Kingdom (of Great Britain and Northern Ireland)
20415	87	27	87	31	cross-border cost reduction has been quantified for Europe to 10% and 26 billion EUR per year by Child et al. (https://www.sciencedirect.com/science/article/pii/S0960148119302319); a more global view on cross-border integration benefits is provided by Breyer et al. (https://onlinelibrary.wiley.com/doi/10.1002/pip.2885 ; https://www.iaee.org/eeep/article/305)	We appreciate your suggestion. 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 merit inclusion in 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
37425	87	32	87	36	description of options for dispatchable generation is misleading as variable RE and storage also provides dispatchable generation.	We include "on-demand" in the description to designate that our use of "dispatchable" here focuses on non-energy-limited resources that can provide output at rated capacity when called on to do so. This is narrower than options that are merely flexible (e.g., adjusting wind/solar output downward from curtailment) or energy limited (e.g., battery storage).	Michiel Schaeffer	Climate Analytics	Netherlands
12405	87	32			Dispatchable flexible fossile fuel with CCS?	Flexible units with or without CCS could be included.	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
43731	87	42	88	5	I note an excellent report by Bloomberg New Energy Finance examining different balancing approaches (UK) including comparing weightings towards interconnection, battery storage, EVs, V2G, and the cost and CO2 implications for 2030 and 2040 timeframes. "Flexibility Solutions for High-Renewable Energy Systems', November 2018. [https://about.bnef.com/blog/flexibility-solutions-high-renewable-energy-systems/]	This is a good report. 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 merit inclusion in this section.	Kirsty Hamilton	Chatham House (Associate Fellow, unpaid)	United Kingdom (of Great Britain and Northern Ireland)
6397	87	47	87	48	the sentence claims that 'there are no inherent limitations on the maximum renewable penetration on a grid'. This statement should be supported with adequate reference. There is a number or works which claim that very high penetration of renewable in the energy system might actually pose technical challenges and not without limits.	We clarified this sentence by replacing "limitations" with "upper bounds."	Sciacovelli Adriano	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
42383	87	47	88	2	The economic feasibility of high VRE systems depends on model capability to handle several issues as it also depends on assumed technology costs. Most parametrization that are used in models that are typical of the present power system lack the capability to measure the economic feasibility of the future high VRE grid because it limits the ability to design an optimal system [1,2]. There are several studies that tried a different approach and reported an affordable price. However, this is not intended to down play the presence of high uncertainty in those studies. Nonetheless there is no doubt that the presence of such reports makes statements such as this one questionable. 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 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.	We appreciate the reviewer's suggestions. The cited papers for this sentence acknowledge the dependence of the least-cost mix on technological cost and performance assumptions. The cited papers focus on least-cost mixes and not necessarily on satisficing solutions, as the reviewer notes.	Solomon Asfaw	LUT University	Finland
6461	88	2	88	4	It should be added that also the returns might decrease or increase if the capacity/availability of other flexibility options changes. See e.g. Neetzow, P., Pechan, A., Eisenack, K., 2018b. Electricity storage and transmission: complements or substitutes? Energy Econ. 76, 367–377.	We expanded this sentence to note that these options may be complements or substitutes to each other.	Paul Neetzow	Humboldt-Universität zu Berlin	Germany
9023	88	6	88	7	There are a lot more 100% scenarios than the Jacobsen study which spurred a lot of controversy. Currently, the text could be understood to imply that there is only one study. To ensure that this is a balanced review, I suggest to include more references, for example, the literature given below. References Brown, T. W. et al. Response to 'Burden of proof: A comprehensive review of the feasibility of 100% renewable-electricity systems'. Renewable and Sustainable Energy Reviews 92, 834–847 (2018). Burandt, T., Xiong, B., Löffler, K. & Oei, P.-Y. Decarbonizing China's energy system – Modeling the transformation of the electricity, transportation, heat, and industrial sectors. Applied Energy 255, 113820 (2019). Tröndle, T., Pfenninger, S. & Lilliestam, J. Home-made or imported: On the possibility for renewable electricity autarky on all scales in Europe. Energy Strategy Reviews 26, 100388 (2019). Zappa, W., Junginger, M. & van den Broek, M. Is a 100% renewable European power system feasible by 2050? Applied Energy 233–234, 1027–1050 (2019).	We appreciate the reviewer's good suggestions. We included a review paper (Hansen, et al.) that includes a broader range of 100% renewables scenarios.	Jan Wohland	ETH Zürich	Switzerland
17077	88	6	88	7	Although Jacobson et al. are more visible on the public debate, it would not be fair to mention this as the main source of 100% renewable scenarios. Others have done much better, more detailed work, and are not controversial, like Beryer and Brown mentioned in other comments, but also Zappa, Jenkins, etc. etc.	We agree with the reviewer and added a literature review by Hansen, et al. (2019) that includes a broader range of scenarios instead of citing a single study.	Kornelis Blok	Delft University of Technology	Netherlands
37427	88	6	88	7	Jaconson et al 2015 is an old citation for 100% RE scenarios. E.g., Hansen et al 2019 (https://www.sciencedirect.com/science/article/abs/pii/S0360544219304967) provides a more up to date overview	Thank you for the good suggestion. We used the Hansen, et al. literature review instead of citing a single study.	Michiel Schaeffer	Climate Analytics	Netherlands

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
27921	88	6	88	8	The IPCC states, "Scenarios with 100% renewable electricity systems are emerging in the literature e.g., (Jacobson et al. 2015) however, some of these studies have generated controversy for their input assumptions, model simplifications, and framing (e.g., (Clack et al. 2017))." This statement is highly misleading and possibly the only occurrence in all 17 IPCC chapters where a study is criticized. First, two independent review articles debunked virtually all the Clack et al. (2017) claims and upheld the finding in Jacobson et al. (2015) that 100% renewables is feasible. Specifically, Diesendorf, M., and B. Elliston, The feasibility of 100% renewable electricity systems: A response to critics, Renewable and Sustainable Energy Reviews, 93, 318-330, 2018, state "Our assessment is that Jacobson et al. [78] have clearly refuted all but one of Clack et al. [33] error claims. The exception is Jacobson's assumption of a huge and unrealistic increase in hydro capacity by installing additional turbines on existing dams, in order to assist in balancing variable RElec. However, this is a minor 'error', because a large part of the additional hydro could be replaced by alternatives such as CST with thermal storage, OCGTs fueled by renewable hydrogen or ammonia, new off-river pumped hydro and batteries. Of particular concern is that PNAS published the Clack et al. [33] article as a Research Report instead of a Letter to the Editor, although the article contained no original research – it only criticised a genuine research paper with claims that generally don't stand up to examination." They also state, "the main critiques (including Clack et al.) published in scholarly articles and books contain factual errors, questionable assumptions, important omissions, internal inconsistencies, exaggerations of limitations and irrelevant arguments." Similarly, Brown, T.W., T. Bischof-Niemz, K. Blok, C. Breyer, H. Lund, and B.V. Mathiesen, Response to 'Burden of proof: A comprehensive review of the feasibility of 100% renewable electricity systems,' Renewable and Sustainable Energy Reviews, 92, 834-847, 2018, state "As a result, we conclude that the 100% renewable energy scenarios proposed in the literature (including Jacobson et al. 2015) are not just feasible, but also viable."	We agree that it is more appropriate to cite a literature review rather than a single study. We replaced the Jacobson, et al. reference with the Hansen, et al. review.	Mark Jacobson	Stanford University	United States of America
27921					Comment continued: Please address this issue by citing Diesendorf and Elliston and Brown et al. as articles that indicate that the claims of Clack et al. were misplaced. Second, the conclusions of the Clack et al. paper are based on factually false information that the primary authors of the Clack et al. paper have admitted to in writing: http://web.stanford.edu/group/efmh/jacobson/Articles/I/CombiningRenew/AdmissionsC17.pdf As such, the IPCCclarify that the Clack et al. paper's two main conclusions are based on false statements that the authors of the Clack et al. paper have admitted to in writing. Third, there are 47 papers by 13 independent resarch groups and over 90 authors that find 100% renewable energy is feasible at low cost throughout the world http://web.stanford.edu/group/efmh/jacobson/Articles/I/CombiningRenew/100PercentPaperAbstracts.pdf , so the conclusion from Jacobson et al. (2015) is robust and not controversial among the preponderance of experts on high penetration levels of renewables. Critics of 100% renewables are in a clear minority in the field.		Mark Jacobson	Stanford University	United States of America
39201	88	6	88	8	The literature on 100% renewable systems is much wider than just Jacobson, and covers all energy sectors (electricity, heating, transport and industry), see for example the recent reviews Brown et al https://doi.org/10.1016/j.energy.2019.03.092 and Hansen et al https://doi.org/10.1016/j.energy.2019.03.092	We agree and replaced the Jacobson, et al. reference with the Hansen, et al. literature review.	Tom Brown	Karlsruhe Institute of Technology	Germany
45073	88	6	88	8	The content that has been allocated to this box may be transformed into a more extensive section. The statement "scenarios with 100% renewable electricity systems are emerging in the literature directly" is currently given only 1 reference. Additional representation of related studies would be beneficial also with a focus on the energy transition.	We agree and replaced the Jacobson, et al. reference with the Hansen, et al. literature review.	Siir Kilkis	The Scientific and Technological Research Council of Turkey	Turkey
20333	88	6	88	18	I am shocked by this lack of knowledge of literature!!! MAJOR revision of this part is mandatory. Brown et al. (https://www.sciencedirect.com/science/article/pii/S1364032118303307) broadly discussed standard items for 100% renewables. Hansen et al. (https://www.sciencedirect.com/science/article/pii/S0360544219304967) provides a broad overview on existing literature with reference to 180 (!) articles in the field. Bogdanov et al. (https://www.nature.com/articles/s41467-019-08855-1) provide the first full hourly global-local 100% RE transition scenario. Child et al. (https://www.sciencedirect.com/science/article/pii/S0960148119302319) disusses 100% RE for Europe and provides an overview on literature. Aghohosseini et al. (https://www.sciencedirect.com/science/article/pii/S1364032119300504) discusses 100% RE for the Americas with a broad literature overview. BTW, Clack et al. is a rather weak reference, since they heaviliy complain about Jacobson et al. and 100% RE, BUT do not set a single reference to any of the other >100 articles in the field which existed at that time - which documents a poor scientific style or poor literature knowledge or both. Substantial revision of this entire section is required. It is simply not true that economics of 100% renewables would be highly challenging: study Bogdanov et al., Child et al., Agahosseini et al., Ram et al. (http://energywatchgroup.org/wp-content/uploads/EWG_LUT_100RE_All_Sectors_Global_Report_2019.pdf) - they ALL have a different conclusion.	We included the Hansen, et al. literature review at the beginning of this paragraph.	Christian Breyer	LUT University	Finland

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
37429	88	6	88	18	This section tends to be prescriptive regarding the literature assessment. A more balanced discussion is needed. For example, IAMs are known to have relatively outdated assumptions related to renewable and storage costs, as well as poor representations of integration requirements. See, e.g., Creutzig et al. (2017). The underestimated potential of solar energy to mitigate climate change. https://doi.org/10.1038/nenergy.2017.140.	We agree that the limitations of IAMs vis-à-vis detailed energy system models are insufficiently understood. We added sentences to this paragraph to place modeling strengths and shortcomings in context.	Michiel Schaeffer	Climate Analytics	Netherlands
42385	88	6	88	18	Please take a note of my previous comment that 100% RE is not simply 100% VRE. I would like to note three issues on this paragraph: 1. As someone who have worked on the subject for over a decade, I fully recognize the present limitation in modelling of the future energy system of all kind that anticipates high VRE (not only 100 VRE). However, models that are used to evaluate the high VRE grid and reported high cost for 100 % VRE also suffers a limit of various kind. They basically apply the concept of the present grid to the future grid and they also study the system with a limited technology database (particularly storage technologies). This is wrong from the very beginning. Given the way we handle our-selves now, I will not be surprised if transitioning to 60% VRE become a disaster (not 100% VRE). 2. There are several other studies that have evaluated 100% RE grid outside USA, I don't know why they did not receive any attention at all. But this is not a confirmation of their accuracy but the need to broaden the scope of the discussion because of the presence of plausible cases for 100% RE. 3. This is an appeal. I have been following these debates on 100% RE (VRE in this case) and the one about no/pro-nuclear. In my view, the debate between both extremes reduces the big challenge of addressing climate change to a simple bickering between groups with various thought. It is also a reflection of doubtfulness in our ability to innovate. This can be resolved if civil discourse is motivated by valuing all views equally and motivating more innovative research by showing the direction. I believe IPCC has that capability. As I noted in my other comments, one of the negative criticisms of the high VRE grid emanates from lack of sufficient understanding of the physics of the system. Clarifying the present state of the research and motivating more innovative research in the area will be outstanding. I also don't understand why any one will be opposed to an innovative new nuclear technology because it bears the name "nuclear". Thus, it is better to highlight all views equally and point to the required research options and lead the process.	We appreciate the reviewer's thoughtful suggestions. Although we do not have the space in this box to fully address all of these issues thoroughly, we added references and text to this paragraph to note other studies and strengths/limitations of various modeling approaches.	Solomon Asfaw	LUT University	Finland
27923	88	8	88	12	The IPCC claim "Deep decarbonization analyses, including multimodel comparison studies with detailed models of power sector investments and operations, indicate large roles for variable renewables, but least-cost pathways for meeting emissions reduction targets rarely suggest near 100% wind and solar mixes unless optimistic assumptions about integration challenges are combined with pessimistic assumptions about alternatives." This statement is debunked not only by Diesendorf, M., and B. Elliston, The feasibility of 100% renewable electricity systems: A response to critics, Renewable and Sustainable Energy Reviews, 93, 318-330, 2018, who conclude, "the main critiques published in scholarly articles and books contain factual errors, questionable assumptions, important omissions, internal inconsistencies, exaggerations of limitations and irrelevant arguments" and Brown, T.W., T. Bischof-Niemz, K. Blok, C. Breyer, H. Lund, and B.V. Mathiesen, Response to 'Burden of proof: A comprehensive review of the feasibility of 100% renewable electricity systems,' Renewable and Sustainable Energy Reviews, 92, 834-847, 2018, who state "As a result, we conclude that the 100% renewable energy scenarios proposed in the literature are not just feasible, but also viable, "but also by 47 peer-reviewed papers among 13 independent research groups that find 100% renewables is feasible at low cost (http://web.stanford.edu/group/efmh/jacobson/Articles/I/CombiningRenew/100PercentPaperAbstracts.pdf). Please correct this statement to indicate that independent review papers debunk Jenkins and Bistline's claims.	The papers referenced by the reviewer do not contradict the claims made in this paragraph. The feasibility/viability of 100% renewable systems are not at issue but whether they are least-cost decarbonization pathways.	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
27925	88	13	88	14	IPCC claims "Although many studies find 100% renewable systems technically conceivable, economic and operational challenges increase sharply as shares approach 100 percent." This statement is contradicted by many of the 47 peer-reviewed studies that find low-cost renewables with 100% renewable energy (http://web.stanford.edu/group/efmh/jacobson/Articles/I/CombiningRenew/100PercentPaperAbstracts.pdf). Specifically, for example, the following two papers find costs, averaged across all energy sectors, of a 100% clean, renewable Wind-Water-Solar (WWS) system in 143 and 139 countries, respectively, to be much lower than BAU fuel costs: 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. https://web.stanford.edu/group/efmh/jacobson/Articles/I/WWS-50-USState-plans.html and 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, https://doi.org/10.1016/j.renene.2018.02.009, https://web.stanford.edu/group/efmh/jacobson/Articles/I/CombiningRenew/WorldGridIntegration.pdf . These papers, therefore, debunk the claims that costs "increase sharply." Please include these references to contradict this claim.	We thank the reviewer for their recommended references. The analyses cited in this section (including a nice study by the reviewer) vary renewable shares and plot metrics (e.g., costs/revenues, curtailments) across this range. However, the papers cited by the reviewer primarily examine a 100% renewable system and compare it with another ad hoc "BAU" system. Importantly, the BAU system may not be one that is cost minimizing given the set of equivalent market/policy goals, so the assessment of relative cost is not a meaningful metric.	Mark Jacobson	Stanford University	United States of America
27927	88	13	88	14	IPCC claims "Although many studies find 100% renewable systems technically conceivable, economic and operational challenges increase sharply as shares approach 100 percent." The reasons for this erroneous statement are described in detail on pages 457-458 of 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. The text finds, for example, that two particular studies (Shaner et al., 2018; Sepulveda et al., 2018) that have made this claim use the wrong tools to even evaluate the claim because they do not electrify all energy sectors, do not include all heat/cold/hydrogen/electricity storage options, lowball nuclear and CCS costs, ignore planning-to-operation delays of nuclear and CCS, ignore the fact that CCS doesn't reduce nearly so much carbon as claimed, do not treat demand response, do not treat district heating thus seasonal thermal energy storage, etc., etc. Please clarify the text by identifying the processes missing in these studies or withdraw the claim. It is highly misleading simply to state some studies dismiss findings of other studies without clarifying the critical missing information in the critiques themselves.	We expanded this paragraph to discuss the relative strengths and shortcomings of different modeling approaches.	Mark Jacobson	Stanford University	United States of America
5655	88	13	88	18	The reference included in my Comment #14 above is also helpful for this passage, as it suggests that decarbonization relying only on intermittent renewables becomes very expensive as the emissions target falls closer and closer to zero emissions.	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 Jayadev, et al. (2020) paper looks at decarbonization scenarios in the U.S. but does not conduct experiments where renewable shares are varied.	Benjamin Leibowicz	The University of Texas at Austin	United States of America
20419	88	13	88	18	there are several country studies clearly indicating that a 100% renewable system is lower in cost then systems with shares of nuclear and or fossil CCS, such as for Nigeria (https://www.sciencedirect.com/science/article/pii/S0196890418311361), South Africa (https://www.sciencedirect.com/science/article/pii/S0038092X19309144), Israel (https://www.sciencedirect.com/science/article/abs/pii/S036054421830834X), Sweden (https://www.sciencedirect.com/science/article/pii/S0360544220301225), Iran (https://www.sciencedirect.com/science/article/pii/S0960148119309139), Finland (https://www.sciencedirect.com/science/article/pii/S1364032116303306); while Ram et al. has shown the comparison for all G20 countries and 2030 technology status (https://www.sciencedirect.com/science/article/pii/S0959652618321486)	Note that this paragraph does not suggest that 100% renewable systems are never the least-cost decarbonization portfolios. Instead, it notes that, according to the current body of literature on least-cost decarbonization strategies, the number of 100% wind and solar mixes is small relative to ones that also include other technologies.	Christian Breyer	LUT University	Finland
17079	88	14	88	14	It is exactly these operational challenges (and how they can be overcome) that are discussed extensively in the Brown et al. (in the reference list).	We included the Brown, et al. study in this paragraph.	Kornelis Blok	Delft University of Technology	Netherlands
17083	88	15	88	18	This is such an important topic and so many papers have been published on this since 2014, that these few lines are not appropriate. As a policy maker, I would like to know: at what penetration do costs start increasing? What are the cost penalties of high renewable shares? And to what extent is it possible to avoid these cost increases by addiing more flexibility to the system?	Note that this sentence cites papers and surveys that represent the broad literature over the last several years. There is not enough room in this box to provide answers to the questions posed by the reviewer (and the answers are very context dependent), which is why the citations provide more in depth discussions of these issues.	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
20421	88	19	88	39	references are missing for this important section. Ram et al. (http://energywatchgroup.org/wp-content/uploads/EWG_LUT_100RE_All_Sectors_Global_Report_2019.pdf) show exactly what is written, while Khalili et al. (https://www.mdpi.com/1996-1073/12/20/3870) show a strong electrification for the transport sector	Accepted. The section has been revised to include references for statements about electrification of end-uses.	Christian Breyer	LUT University	Finland
45467	88	21	88	24	Why is a cost-effective path for deep decarbonization electrification of end uses? Some explanation here will help. Would bioenergy	Accepted. Explanation has been added in this section to highlight when electrification of end-uses is a cost effective strategy for deep decarbonization.	Girija Parthasarathy	Thermo King	United States of America
4483	88	22	88	23	Please mention the literature this claim is based upon	Accepted. The claims made in this section are backed up with literature references.	Leonardo Barreto	Austrian Energy Agency	Austria
42029	88	27	88	28	"... large investements in a charging infrastructure AND IN STRENGTHENING EXISTING POWER NETWORKS"	This text has been modified from the previous iteration, and this comment is no longer applicable.	Francisco Javier Hurtado Albir	European Patent Office	Germany
45383	88	28	88	29	Policy and building codes changes at a local level supporting full electrification of new residential and some commercial construcution have begun to be implemented in California (multiple cities - likely other locales as well)	Noted.	Deborah Knuckey	Published energy journalist plus consultant for renewable energy development and finance companies through Kiterocket	United States of America
16459	88	40	88	41	Can we first define the hard-to-decarbonize sectors? What are these sectors? Transportation?	The revised section begins with an introduction of these sectors.	Xunzhang Pan	School of Economics and Management, China University of Petroleum, Beijing 102249, China	China
34409	88	41	89	1	References and an updated discussion is missing here. To reach the goal of net zero emissions, fossil fuel-based energy demand could be mainly replaced by renewable electricity (RE) (e.g. DENA, 2017, Ram et al., 2019). However, there are sectors such as aviation, shipping, heavy transportation, energy intensive industries for which hydrocarbons cannot be replaced by electricity easily, or physically not at all (e.g. Fasihi et al., 2017, Hepburn et al., 2019, SDSN &FEEM, 2019). Biofuel production is faced with resource limitations and conflicts with food production and, therefore, offers no sustainable substitute (Koizumi et al., 2015, Tomei et al., 2016). Net zero emissions could be achieved by a defossilization of the energy system, whereby carbon from fossil sources is replaced by that which is created synthetically and sustainably from CO2 with the aid of RE. These CO2-based fuels can be emission neutral and be used in the current fossil fuel-based infrastructure (DENA, 2017, Fasihi et al., 2017, Art et al., 2019, CONCAWE, 2019). Power to fuel is the concept enabling the production of hydrocarbon fuels (e-fuels) using RE. Two types of fuels can be generated: 1) Synthetic gas (e.g. e-methane) so-called Power-to-Gas and 2) Liquid fuels (e.g. methanol, ethanol), so-called Power-to-Liquid. In both cases, CO2 and green H2 (i.e. hydrogen generated by the electrolysis of water with RE) produce e-fuel (e.g. Breyer et al., 2015, Sternberg and Bardow, 2015, Dimitrou et al., 2015, Fasihi et al., 2017, Anwar et al., 2020). These e-fuels can be stored, transported and use as such or to produce electricity again. Liquid e-fuels are easier (and relatively inexpensive) to store and transport compared to electricity. They can be kept in large-scale stationary storage over extended periods, and mobile storage in vehicle tanks, which can compensate for seasonal supply fluctuations and contribute to enhancing energy security (CONCAWE, 2019). Artz et al., 2019 has 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 in so called “Power-to-fuel” scenarios. Using power-to-fuel to meet the expected remaining fuel demand for aviation in 2050 would require renewable electricity equivalent to some 28% of Europe’s total electricity generation in 2015. However, with today’s technology, synthetic fuels are the only technically viable solution that would allow aviation to exist in	We appreciate the suggested references. The revised section has been expanded and new references included.	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
18737	88	44	88	45	Such energy-dense fuels may be critical sectors that are difficult to electrify)' - missing words? Could be 'Such energy-dense fuels may be necessary for critical sectors that are difficult to electrify.'	Revised, thanks.	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
12647	89	3	89	3	The potential benefits of sector coupling are not well included (i.e. coupling power, heating/cooling, transport and PtX). There is broad consensus that sector coupling will facilitate electrication, balancing of the power side as well as improve efficiency of the green transition. Please include this aspect. See e.g. https://www.etip-snet.eu/wp-content/uploads/2020/02/ETIP-SNEP-Sector-Coupling-Concepts-state-of-the-art-and-perspectives-WG1.pdf . There is e.g. a potential high benefit of producing bio-fuels bossted with hydrogen from electricity and utilising excess heat for district heating. See e.g. https://doi.org/10.1016/j.esr.2019.100446	The revised section discusses the potential advantages of integrating electricity, industry and transportation systems.	Marie Münster	Technical University of Denmark	Denmark

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20423	89	3	89	7	literature may be limited, but still some references can be shown, how it can be done: Ram et al. (http://energywatchgroup.org/wp-content/uploads/EWG_LUT_100RE_All_Sectors_Global_Report_2019.pdf) for the entire energy system; Horvath et al. (https://www.sciencedirect.com/science/article/pii/S0196890418302152) for the marine sector; Fasihi et al. (https://www.sciencedirect.com/science/article/pii/S1876610216310761) for Fischer-Tropsch; and Khalili et al. (https://www.mdpi.com/1996-1073/12/20/3870) in a comprehensive overview on the transport sector	The suggested references are appreciated.	Christian Breyer	LUT University	Finland
34411	89	3	89	7	Here again, the discussion is based on 1 article and the debate on alternatives for the industries is totally missing. CCU is the key alternative for the hard to abate industry and many technologies are at a relatively high readiness level. What is missing for a large scale deployment are proper policy incentives, e.g. the addition of CCU in the ETS and the development of a CO2 market. For CCU, individual business cases are already providing incentives for different actors today. A higher price for emission allowances could further strengthen the incentives for both CCU and CCS (Bruhn et al., 2016, Castillo-Castillo 2019). CCU likely represents a promising perspective for contributing to climate mitigation efforts but considerations of CCU in climate scenarios and in politics need to account for the largely varying and technology specific features of each type of technology and sector. Moreover, the key role of CCU as a vector to move away from fossil fuel resources should be the first point highlighted. Hepburn et al, 2019 shows that 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 ton of CO2—increasing over time—to penalize CO2 emissions and to incentivize verifiable CO2 emissions reductions and removals from the atmosphere. The European SCO2T project concluded that CCU can make important contributions in Europe, by becoming a significant component in the future low-carbon circular economy and facilitating the energy transition (Wilson et al., 2016). (Hepburn et al., 2019: The technological and economic prospects for CO2 utilization and removal, 575, 87-97./ Wilson et al., 2016: Astrategic european research and innovation agenda for Smart CO2Transformation in Europe. Smart CO2Transformation (SCO2T) project 978-0-9572588-5-3./Bruhn et al., 2016, Environmental Science & Policy, 60, 38–43./Castillo-Castillo, 2019, Policy analysis and recommendations for EU CO2 utilisation policies. In: CEST2017 15th International Conference on Environmental Science and Technology, Rhodes, Greece./CCES, 2019: Carbon Utilization – A vital and effective pathway for decarbonization, Center for Climate and Energy Solutions)	The revised section includes expanded discussion of industry and CCU, and incorporates many of the suggested references.	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
17023	89	8	89	11	As for liquid biofuels for transportation sector, renewable bio-jet fuel of aviation industry with a potential to reduce carbon emission is suggested to add.	The revised section is explicit about the potential uses of biofuels, including kerosene-type jet fuel.	Qing YANG	Harvard University	China
20633	89	9	89	11	Their life cycle carbon emissions have been shown to be stronly dependent on production location (for energy crops). However the time horizon for GHG accounting is very important. The potential for biofuels at low life-cycle emissions have been shown to be quite limited (approx 1 EJ, globally) at time horizons of 20 years. Daioglou, V., Doelman, J. C., Stehfest, E., Müller, C., Wicke, B., Faaij, A., & van Vuuren, D. P. (2017). Greenhouse gas emission curves for advanced biofuel supply chains. Nature Climate Change, 7(12), 920-924.	Unclear what study is being referred to.	Vassilis Daioglou	Copernicus Institute of Sustainable Development	Netherlands
4485	89	10	89	11	should it read "These biofuels could conceivably be targeted to difficult-to-decarbonize sectors, because they face substantial challenges related to their life-cycle carbon emissions, cost, and further scalability?	The list of challenges here refers to the biofuels not the difficult sectors.	Leonardo Barreto	Austrian Energy Agency	Austria
27967	89	10	89	11	IPCC states, "These biofuels could conceivably be targeted to difficult-to-decarbonize sectors, but face substantial challenges related to their life-cycle carbon emissions, cost, and further scalability." Please add an additional problem with biofuels, namely their impact on air pollution mortality: Jacobson, M.Z., Effects of ethanol (E85) versus gasoline vehicles on cancer and mortality in the United States, Environ. Sci. Technol., 41 (11), 4150-4157, doi:10.1021/es062085v, 2007; Jacobson, M.Z., Review of solutions to global warming, air pollution, and energy security, Energy & Environmental Science, 2, 148-173, doi:10.1039/b809990c, 2009; Ginnebaugh, D.L., J. Liang, and M.Z. Jacobson, Examining the temperature dependence of ethanol (E85) versus gasoline emissions on air pollution with a largely-explicit chemical mechanism, Atmos. Environ., 44, 1192-1199, doi:10.1016/j.atmosenv.2009.12.024, 2010	The revised text mentions air pollution as another challenge related to biofuels.	Mark Jacobson	Stanford University	United States of America
4487	89	12	89	16	It should be mentioned that compliance with biomass sustainability and GHG savings criteria for biofuels by economic operators is essential to make sure that biofuels contribute to a low-carbon energy system	This issue is noted as "challenges related to life-cycle carbon emissions...and further scalability."	Leonardo Barreto	Austrian Energy Agency	Austria

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20635	89	12	89	16	The extent of biomass use in future energy systems, and the sensitivies and uncertainties thereoff, have been extensively analysed by IAMs. Particularily the EMF-33 intercomparison project offers a plethora of information concerning the role biomass plays in decarbonising the energy system and what the critical elements are. EMF-33 overview: Bauer, N., Rose, S. K., Fujimori, S., Van Vuuren, D. P., Weyant, J., Wise, M., ... & Kitous, A. (2018). Global energy sector emission reductions and bioenergy use: overview of the bioenergy demand phase of the EMF-33 model comparison. Climatic Change, 1-16. Use of residues acorss models: Hanssen, S. V., Daioglou, V., Steinmann, Z. J., Frank, S., Popp, A., Brunelle, T., ... & Van Vuuren, D. P. (2019). Biomass residues as twenty-first century bioenergy feedstock—a comparison of eight integrated assessment models. Climatic Change, 1-18. Uncertainties concerning deployment of different bioenergy technologies (under review): DAIOGLOU, V., ROSE, S., BAUER, N., KITOUS, A., MURATORI, M., SANO, F., FUJIMORI, S., GIDDEN, M., KATO, E., KERAMIDAS, K., KLEIN, D., LEBLANC, F., TSUTSUI, J., WISE, M. & VAN VUUREN, D. in review. Bioenergy technologies and climate change mitigation pathways: Results from the EMF33 study. Climatic Change. Bioenergy across different socio-economic pathways - uncetainties concerning land-use and technological futures: Daioglou, V., Doelman, J. C., Wicke, B., Faaij, A., & van Vuuren, D. P. (2019). Integrated assessment of biomass supply and demand in climate change mitigation scenarios. Global environmental change, 54, 88-101.	The revised text references the EMF-33.	Vassilis Daioglou	Copernicus Institute of Sustainable Development	Netherlands
23939	89	13	89	13	instead of "that enable use of use of feedstocks" it should be " that introduce further introduce the use". There are already a number of large scale demonstration plants prodiving liquid fuels from biomass	Next-generation biofuels using the cellulosic feedstocks have not been proven economical at scale. The references cited support the sentence as written.	Stefan Majer	German Biomass Research Centre - DBFZ	Germany
25081	89	13	89	13	Delete "of use"	Revised thank you.	Eleni Kaditi	Organization of the Petroleum Exporting Countries (OPEC)	Austria
36521	89	23	89	24	Which hydrogen, reforming or electrolysis, used for “minimum” price? It is assumed from electrolysis but not clear.	clarified electrolytic, thank you	Takashi Hongo	Mitsui & Co. Global Strategic Studies Institute	Japan
5725	89	26	89	26	The statement about electrolyser cost reductions of 60 - 80 % being targetted is fine, but this is a cost reduction FOR the immature technologies, NOT alkaline electrolysis, which is mature and will not in any way have such reductions. This is important, because it will be tempting for people to look up the costs for AE, knock 80 % off them, and then suggest that these might be acheivabe targets.	clarified, thank you	paul fennell	Imperial College	United Kingdom (of Great Britain and Northern Ireland)
12903	89	27	89	27	Thermochemical water splitting using High Temperature Nuclear Reactors may be added	thermochemical water splitting is mentioned. no sources of heat are specified.	ASHOK NEMA	Nuclear Power Corporation of India Limited	India
20425	89	30	89	34	latest literature insights clearly indicate that cost around 50 EUR/tCO2 captured are possible by 2050: https://www.cell.com/joule/fulltext/S2542-4351(19)30413-1 ; https://www.sciencedirect.com/science/article/pii/S0959652619307772	The revised text has been updated to include additional literature, including the suggested references	Christian Breyer	LUT University	Finland
14277	90	1	90	1	a thin red line and an arrow towards B. demand for structural materials is needed.	The black arrow in the diagram shows the demand for materials. Carbon may be contained within.	Anastasios Perimenis	CO2 Value Europe (Association) - CCU Offiver	Belgium
11549	90	4	91	19	The Hydrogen economy can only be carbon neutral if the hydrogen is produced in a carbon neutral way. Hydrogen itself is not a fuel but an energy carrier.	Correct. We mentioned therefore hydrogen production through fossil fuels with CCS (where with BECCS even negative emissions can be achieved.). Regarding the scond part, as Siemens annouced in 2030, they will run gas turbines fully with hydrogen, and hence it can be also as a fuel.	Arnulf JÄGER-WALDAU	European Commission, JRC	Italy
17085	90	4	91	19	Why is this Box not integrated in 6.4.4.1? That one is much more extended.	This is now coordinated	Kornelis Blok	Delft University of Technology	Netherlands
29091	90	4	91	19	Hydrogen box also in Chapter 11. Please see 11-27 for consistency	These are consistemnt	Minal Pathak	Ahmedabad University	India

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34177	90	4			Could use a reminder that hydrogen only has a benefit if it is produced with low carbon emission [suggestion ENSEEIHT INP]	As mentioned we tried to point out hydrogen production with zero/low carbon emissions (in BECCS negative). This indicates that the hydrogen economy becomes only attractove when it is produced low/zero emissions:"In order to release the hydrogen economy meeting the emission targets, hydrogen will need to be produced from zero-carbon energy sources or, if not, offset by means of sequestering carbon from the atmosphere. Hydrogen can be made from natural gas through the process of autothermal reforming (ATR), steam methane reforming (SMR), and gasification of coal combined with carbon capture and storage (CCS) technology that would absorb most of the resulting CO2 (80-90%). However, to reach a carbon-neutral energy system, to abate the greenhouse gas emission; (i) hydrogen should be produces through gasification of biomass with CCS (BECCS) or (ii) the produced CO2 via other hydrogen technologies should be captured from biomass or from direct air capture (DAC) technologies (IRENA 2019). "	Antoine BONDUELLE	Climate Action Network France	France
37431	90	4			box on hydrogen economy - where is literature on perspectives for reducing cost of electrolysers and overall green hydrogen, see report by hydrogen council?	The required text and reference is added: "However, recent developments and improvements in hydrogen production technologies in terms of efficiency and capital costs (e.g. SMR) (CCC, 2018), and emerging of advanced technologies (e.g., mainly electrolysers; SOEC) for hydrogen production are becoming more competitive (Schmidt et al. 2017). In this context, offshore wind-based electrolysis could lead to further 60% cost reduction by 2030 (Hydrogen council 2020)."	Michiel Schaeffer	Climate Analytics	Netherlands
34413	90	5	90	15	This box terribly misses references and updated discussions The use of hydrogen should be discussed in specific time frames and it should be clear that for many application H2 could not be used as energy sources, because of its density, the risks associated to its leaks and to the fact that it would take decades to the industry to adapt their infrastructure to use hydrogen. On shorter time frame, CCU is an alternative, because it allows to use, e.g. synthetic natural gas as power in exisiting infrastructure. .Please add: 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, EU report, 2018). 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 CO2 based fuels, e.g. (Gumber and Gurumoorthy, 2018). 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). (/ Muratori et al., 2018, Energies 2018, 11, 1171./Gumber and Gurumoorthy, 2018, Methanol, Chap. 25, 661-675./Deutz et al., 2018, Energy Environ. Sci., 11, 331./EU, A Clean Planet for All, 2018: A Clean Planet for all A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy, Communication from the EU commission./IEAGHG, 2019a: Putting CO2 to Use – Creating value from emissions, International Energy Agency.)	This sesction is updated with the relevant references. Furthermore the suggested context is added to the report. Statements related to synthetic fuels is added in section 6.4	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
39203	90	7	90	9	The use of hydrogen for feedstocks in the chemicals industry, and potentially also for iron ore reduction, are missing here.	The relevant text and reference is added.	Tom Brown	Karlsruhe Institute of Technology	Germany
26601	90	8			The use of hydrogen for space heating in the urban environment where cheaper alterantives are available is a poor use of a scarce, high exergy resource whose combustion would exacerbate rather than imitgate toxic air quality.	This is not specifically quated in literature	Peter North	Calorem Ltd, Imperial College (part-time PhD student)	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
18739	90	12	90	13	In order to transport hydrogen, for distances within a county or region, the existing gas infrastructure could be used.' - this seems like a over simplification. Yes - there is a great deal of interest in reusing as much of the existing natural gas infrastructure as possible - but it is too early to tell what levels of change would need to take place to reduce risks to an acceptable level (e.g. steel embrittlement, degradation of seals etc.). Regardless of this, the compressors valves and other components will have to be suitable for hydrogen too.	The following text is added to the section: "Global deployment of hydrogen (e.g. Muratori et al., 2018, Gumber and Gurumoorthy, 2018) through the existing gas infrastructures (e.g., within a country) is not feasible. Beside physical barriers, such as steel embrittlement and degradation of seals, reinforcements in compressor stations, valves, new construction routes for pipelines would be required (Gasunie 2019).	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
8827	90	17	90	17	There are also several reports about this topic from the International Renewable Energy Agency.	References from IRENA and IEA is added to this section: International Renewable -Energy Agency (2019). Hydrogen: a renewable energy perspective. International Energy Agency (IEA) (2019). The future of hydrogen: seizing today's opportunities.	Saygın Değer	SHURA Energy Transition Center	Turkey
42971	90	17	90	29	I think that the phrase starting "Costs are the main barrier to synthetic hydrocarbons. Hydrogen is a constituent…" need to be revised and updated for SOD-Draft considering the most recent data available as: IEA "The Future of Hydrogen Seizing today's opportunities" [June 2019; available at <https://www.iea.org/hydrogen2019/> and <https://webstore.iea.org/download/direct/2803>], IRENA "Hydrogen: A renewable energy perspective" [September 2019, available at <https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Sep/IRENA_Hydrogen_2019.pdf>] and Hydrogen Council: "Path to Hydrogen Competitiveness: A Cost Perspective" [January 2020; available at <https://hydrogencouncil.com/wp-content/uploads/2020/01/Path-to-Hydrogen-Competitiveness_Full-Study-1.pdf >].	The text is updated with the mentioned references	MARIO VALENTINO ROMERI	Independent consultant	Italy
12385	90	20	90	20	Should probably be SMR with CCS (CCS is required to give hydrogen with low CO2 footprint)	This is correct. The text is updated:"Hydrogen can be made from natural gas through the process of autothermal reforming (ATR) or steam methane reforming (SMR), combined with carbon capture and storage (CCS) technology that would absorb most of the resulting CO2 (80-90%). "	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
44385	90	21	91	2	"In terms of use of hydrogen [...] provide emission-free power generation": this sentence should be supplemented by at least a bibliography reference!	Furthermore, it has been announced that gas turbines should be able to operate completely on hydrogen by 2030, which could provide low/zero emission power generation (Siemens, 2019).	Pietro Guarato	University of Lausanne	Switzerland
30955	91	1	91	2	GE is already selling turbines woirking with H2, https://www.ge.com/reports/hydrogen-generation-gas-turbines-can-run-abundant-element-universe/ and also https://www.ge.com/power/gas/fuel-capability/hydrogen-fueled-gas-turbines	Yes but these turbines still use blended hydrogen and fully hydrogen-based turbines is still not feasible. The required text and reference is added:"Improvements are emerging quickly in hydrogen use. In power generation, General Electric (GE) gas turbines are now running on fuels that contain a range of 5%-95% volume of hydrogen (GE, 2020). Furthermore, it has been announced that gas turbines should be able to operate completely on hydrogen by 2030, which could provide low/zero emission power generation (Siemens, 2019)."	Pietro Bartocci	University of Perugia	Italy
31507	91	1	91	2	Please replace "emission-free" by "low-emission"	Corrected.	Patrick Jochem	German Aerospace Center (DLR)	Germany
34179	91	2			If hydrogen is produced through low carbon energy…[suggestion ENSEEIHT INP]	We added that to the sentence.	Antoine BONDUELLE	Climate Action Network France	France

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18025	91	14	91	16	Coal and biomass-produced hydrogen can have CCS fitted also. If on Biomass, it becomes carbon-negatve. So yes it is an option in a carbon-neutral energhy system	Thank you for the good suggestion. The following text is provided:"In order to release the hydrogen economy meeting the emission targets, hydrogen will need to be produced from zero-carbon energy sources or, if not, offset by means of sequestering carbon from the atmosphere. Hydrogen can be made from natural gas through the process of autothermal reforming (ATR), steam methane reforming (SMR), and gasification of coal combined with carbon capture and storage (CCS) technology that would absorb most of the resulting CO2 (80-90%). However, to reach a carbon-neutral energy system, to abate the greenhouse gas emission; (i) hydrogen should be produces through gasification of biomass with CCS (BECCS) or (ii) the produced CO2 via other hydrogen technologies should be captured from biomass or from direct air capture (DAC) technologies (IRENA 2019). "	Tim Dixon	IEAGHG	United Kingdom (of Great Britain and Northern Ireland)
17087	91	20	92	4	Should discussing of end-use efficiency not be left to the chapters 9 - 11?	Since we are covering the whole energy system, end-use energy efficiency and demand reduction strategies ought to be presented here, even if briefly. We do refer the reader to Chapters 9 to 11 for more details.	Kornelis Blok	Delft University of Technology	Netherlands
34741	91	20	92	4	Consider expanding the narrative to describe the various approaches for more efficient use of energy and advancement of technology and their applications. It is not important o include information on measurement of energy efficiency as stated in line 3 - 4 on page 92.	This is at least in part covered in Chapters 9-11 and Chapter 12.	Rabiz Foda	Hydro One Networks Inc.	Canada
26603	91	20			Please consider an additrional chapter on the effective use of energy and new strategies that give a more complete insight to the potential for resources savings, something current energy and material efficiency strategies only particailly addiress.	This is at least in part covered in Chapter 12.	Peter North	Calorem Ltd, Imperial College (part-time PhD student)	United Kingdom (of Great Britain and Northern Ireland)
4489	91	23	91	24	The energy efficiency first principle should be mentioned explicitly in this section	A paragraph exemplifying the "energy efficiency first" emphasis in the EU, as well has goals and policy in the USA are now included for illustration.	Leonardo Barreto	Austrian Energy Agency	Austria
23941	91	26	91	26	Energy efficiency can also dramatically increased by converting traditional biomass into modern systems. This is an important especially for subsahara Africa.	That is addressed and described in detail in section 6.4.2.6 Bioenergy, so we didn't add more in this section.	Stefan Majer	German Biomass Research Centre - DBFZ	Germany
44315	91	29	91	29	I suggest to replace cookstove with appliances (appliances including cook stoves)	Done. Changed to "appliances and equipment"	BERTOLDI PAOLO	European Commission	Italy
44317	91	30	91	30	recovery and recycling of flurinated gases is not an energy efficiency action	Removed	BERTOLDI PAOLO	European Commission	Italy
19785	91	30	91	31	It is mentioned that "alternative refrigeration fluids, and recovery and recycling of fluorinated gases, among others" as examples for increasing energy, but reduction of leakages through leakage control and better maintenance can be even a more inmportant factor than those mentioned. This is proved in refrigeration systems in supermarkets and industries	That's a great point, but we the text quoted by the reviewer was removed, as rather than efficiency strategies the issues listed previously and by the reviewer would fall more under maintenance issues.	Adrián Mota-Babiloni	University Jaume I of Castellon	Spain
45469	91	33	91	45	Regarding energy efficiency: The mileage requirements imposed by governments on passenger and other vehicles have already made transportation more efficient. So I am not sure I understand that efficiency measures are left to end users to take up (who may only do so with economic incentives), but as recommendations to policy makers in promoting a low carbon future.	Several measures are still cost-effective to consumers (switching to LEDs, efficient appliances and electronics, building insulation, etc)	Girija Parthasarathy	Thermo King	United States of America
31509	91	33	91	46	You may also introduce the concept of sufficiency here!	Done.	Patrick Jochem	German Aerospace Center (DLR)	Germany
31843	91	33	92	2	The uncertainties around efficiency could also include a brief write-up about rebound effect	We added a short text on rebound effects.	Ashok Sreenivas	Prayas (Energy Group)	India
44319	91	37	91	43	Ch. 9 discusses in details the barriers to energy efficiency and the energy effiiciency gap	We have added another sentence asking the the reader to refer to Chapter 9-11 for more details.	BERTOLDI PAOLO	European Commission	Italy
44321	91	44	92	4	Energy efficiency and energy savings are different concept. What matters are energy savings, which are not easy to measure.	Agrred. We now highlight that point at the very begning of this sub-section.	BERTOLDI PAOLO	European Commission	Italy
39205	92	6	92	9	The text here is relying too much on the Davis et al 2018 paper. While this is a nice review, there was an extensive literature before this paper, see e.g. Aalborg work on Smart Energy Systems https://doi.org/10.1016/j.energy.2008.04.003 https://doi.org/10.1016/j.apenergy.2015.01.075 http://dx.doi.org/10.1016/j.energy.2017.05.123, https://doi.org/10.1016/j.rser.2016.02.025 and others http://dx.doi.org/10.1002/we.224 https://doi.org/10.1016/j.rser.2013.09.012 https://doi.org/10.1016/j.energy.2018.06.222	We added additional references to this section.	Tom Brown	Karlsruhe Institute of Technology	Germany
4491	92	16	92	16	Improved business models are essential for the penetration of carbon-neutral approaches	Noted. We mention the need for new business models in this section.	Leonardo Barreto	Austrian Energy Agency	Austria

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
4495	92	23	92	23	End-use sector coupling involving the electrification of heating and cooling in buidlings, transport and industry sectors while reinforcing the interaction between electricity supply and end-use can be mentioned as one of the long-term sector integration strategies to achieve low-carbon energy systems (Van Nuffel et al., 2018, Sector coupling: how can it be enhanced in the EU to foster grid stability and decarbonise?, Study requested by the ITRE committee) https://www.europarl.europa.eu/RegData/etudes/STUD/2018/626091/IPOL_STU(2018)626091_EN.pdf	Noted. We mention sector coupling from electrification in this section.	Leonardo Barreto	Austrian Energy Agency	Austria
27973	92	23	92	24	IPCC states, "This CDR can be associated with the energy systems either in energy production (e.g., BECCS) or as an energy user (e.g., direct air capture), and will make sense only in countries with sufficient capacity to store carbon." Please be clear that there that a review of the literature suggests that CDR methods today increase CO2 rather than decrease it. Specifically, Sekera, J., and A. Lichtenberger, The carbon capture conundrum: Public need versus private gain, A public policy perspective on carbon dioxide capture, 2020, https://drive.google.com/file/d/1K-BIULOUtfSs5LVCS9ONaDzq7jeFmO-b/view conclude (1) many scientific studies pass synthetic carbon removal methods (e.g., those aside from natural reforestation) off as "climate mitigation" when in reality the methods in play today increase CO2 and (2) laws subsidizing carbon capture and direct air capture increase CO2. In addition, 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 similarly find that CCS/U and DACCS/U are both opportunity costs resulting in hardly any CO2 reduction, even before considering the disposition of CO2, and air pollution and mining increases.	The reviewer mentions CO2 capture rates associated with current projects are low owing to the drivers for these projects (e.g., revenues from enhanced oil recovery). However, the text refers to future projects and systems, which are likely to have different drivers (e.g., climate policy) and designs than systems employed today.	Mark Jacobson	Stanford University	United States of America
27969	92	31	92	34	IPCC states, "For instance, climate-neutral liquid fuels could help to bridge stationary and mobile applications, since fuel markets have more flexibility than instantaneously balanced electricity markets due to the comparative ease and cost of large-scale, long-term storage of chemical fuels." The IPCC is neglecting entirely the air pollution health effects of liquid fuels, which are burned just like gasoline and diesel and cause mortality and morbidity. Any social cost analysis that includes both climate and air pollution effects shows that the continued use of combustion fuels, regardless of the source, has a higher social cost than using battery electric or hydrogen fuel cell vehicles, so it is not clear why the use of synthetic liquid fuels is even being proposed as a solution without discussing the damage they will do.	Noted. Broader discussions of social costs and benefits associated with different CO2-equivalent energy system transformation pathways are provided in the Chapter/Section on Sustainable Development Goals.	Mark Jacobson	Stanford University	United States of America
27971	92	35	92	37	IPCC states, "There are few detailed archetypes of integrated energy systems that provide services with zero-gross or net-negative CO2 emissions, so there is considerable uncertainty about integration and interactions across parts of the system." Please cite the ones that do exist: 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. https://web.stanford.edu/group/efmh/jacobson/Articles/I/WWS-50-USState-plans.html and 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, https://doi.org/10.1016/j.renene.2018.02.009, https://web.stanford.edu/group/efmh/jacobson/Articles/I/CombiningRenew/WorldGridIntegration.pdf and several of the 47 papers cited here http://web.stanford.edu/group/efmh/jacobson/Articles/I/CombiningRenew/100PercentPaperAbstracts.pdf	This paragraph was revised to clarify the gaps and contributions in the literature	Mark Jacobson	Stanford University	United States of America
6463	92	46	92	46	Böhringer with ö not o	The spelling was corrected.	Paul Neetzow	Humboldt-Universität zu Berlin	Germany
45075	93	1	93	5	Referral to energy use and behavioral aspects will benefit from referral to rebound effects as well as Chapter 5.	We added a reference to Chapter 5.	Siir Kilkis	The Scientific and Technological Research Council of Turkey	Turkey
17025	93	6	93	7	"Challenges associated with integrating carbon-neutral energy systems include rapid technological change," The accompanying ecnomic challenges of integrating carbon-neutral energy systems are suggested to be discussed with more content.	We discuss economic challenges in other portions of this section under the more detailed subheadings.	Qing YANG	Harvard University	China
20427	93	16	93	39	differences of BECCS and DACCS shall be described more prominently, as highlighted by Creutzig et al. (https://pubs.rsc.org/en/Content/ArticleLanding/2019/EE/C8EE03682A); the postive features of DACCS are fully missing and requires mentioning: https://www.cell.com/joule/fulltext/S2542-4351(19)30413-1	Accepted. We have added the positive features of DAC (such as granularity, less coordination) and also contrasted the BECCS and DACCS technologies in terms of differences in resource requirements, connections to energy systems etc.	Christian Breyer	LUT University	Finland
44619	93	16	93	39	You should also refer to the CDR sections of ch7 and ch12 here	Accepted. CDR Sections from Chapters 7 and 12 have been noted to show the challenges of CDR for the whole economy i.e. beyond just energy systems.	Oliver Geden	German Institute for International and Security Affairs	Germany

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
2159	93	17			So many placeholders where additional text will be added. This is already an extremely long chapter. Will there be a process of revision where you narrow down your focus?	Noted. The chapter needs to be comprehensive thus long (as are all IPCC chapters)	Amy Townsend-Small	University of Cincinnati	
24675	93	19	93	39	DACCS technologies will be required to reach Carbon-Neutral systems, not only in the "beyond net-zero" configurations ans could be introduced at that point.	Accepted. We have noted that DAC (or other CDR) would likely be required in reaching carbon-neutrality to manage hard-to-decarbonize sectors as well as residual emissions.	Florent LE STRAT	ELECTRICTE DE FRANCE	France
29467	93	31	93	32	This sentence "Whether associated with electricity, liquid fuels, or hydrogen production, BECCS would be associated with energy supply and conversation". Is that last word meant to be "conservation" or "conversion"?	Noted. While the text meant conversion, the second-order draft text has been revised and does not have the exact sentence.	Eve Tamme	Global Carbon Capture and Storage Institute	Belgium
12387	93	32	93	32	should probably be conversion and not conversation	Noted. While the text meant conversion, the second-order draft text has been revised and does not have the exact sentence.	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
12389	93	33	93	33	Unclear which three options it refers to here, please consider to rephrase.	Accepted. The three options alluded to here are electricity, liquid fuels and hydrogen as noted in the text.	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
26241	93	34			these the three different	Noted. Corrected	Sara Budinis	International Energy Agency	
44621	93	36	93	39	You should probably introduce an additional category/case, where you have BECCS with imported biomass and/or exported CO2, see https://www.tandfonline.com/doi/full/10.1080/14693062.2018.1509044 & https://www.nature.com/articles/nclimate3369	Taken into account - covered in Box on regional integration of energy systems.	Oliver Geden	German Institute for International and Security Affairs	Germany
31845	93	40	93	40	Section 6.6.3 doesn't seem to touch upon issues such as energy security, land use, jobs, local air quality, and local political economies, which are also institutional and social characteristics of carbon neutrality.	Noted. These have institutional dimensions but do not fit the typology we use, and are extensively discussed in other parts of the report (including other chapters and in the feasibility assessments)	Ashok Sreenivas	Prayas (Energy Group)	
10907	93	40	95	10	The FOD notes that 6.6.3 has a placeholder for the addition of further discussion of societies acceptance of and interaction with carbon-neutral energy systems in the SOD. However, the placeholder is ambiguous about whether the discussion of institutional change will also be expanded. It is very brief at present and needs substantial elaboration and cross-referencing with Chapter 11. Robust review of this section should be made a priority for the SOD to ensure it is sufficiently detailed and policy relevant to provide useful information to UNFCCC parties.	Noted. Corrected	Ian Bailey	University of Plymouth	
31683	93	42	93	42	Are companies included in organizations ? It may be time to explicitly say that the current economic model of companies is not adapted to a post-carbon society.	Noted. Yes, they are included	Alan BURLOT	Commissariat à l'énergie atomique et aux énergies alternatives	
6465	93	44	93	44	Something missing here	Noted. Corrected	Paul Neetzow	Humboldt-Universität zu Berlin	
5219	93	44	94	44	Sentence not finished.	Noted. Corrected	Andreas Oberheitmann	FOM University of Applied Sciences	
12391	93	46	93	46	Please refer to Figure 6.33	Noted. Corrected	Maria Malene Kvalevåg	Norwegian Environment Agency	
45477	93				Section 6.6.3 highlights the very important role of institutional change: is there a summary of institutional changes required worldwide, similar to the 4 listed for United States? Are there studies/ideas on how these institutional changes can be best brought about?	Noted. No, the work has not been done internationally, so we are limited by what the peer reviewed literature says, thus mentioning the USA, as it appears in a study	Girija Parthasarathy	Thermo King	
4497	94	1	94	5	Integration of strategic planning and reporting on the implementation of climate and energy policies and coordination between actors responsible for energy and climate policy is necessary to achieve decarbonisation of energy systems (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)	Noted, We agree, noted	Leonardo Barreto	Austrian Energy Agency	
25083	94	1	94	16	Delete reference to terms such as "green growth"	Noted. This is a term in the literature and thus we will keep it	Eleni Kaditi	Organization of the Petroleum Exporting Countries (OPEC)	
18741	94	8	94	8	will need to new regulatory ...' - missing word - possibly 'will need to develop new regulatory ...'	Accepted, corrected	Grant Wilson	University of Birmingham	
17715	95	11	97	15	This section makes me reflect whether there is a "fith theme" that the chapter could flag at outset - the globalisation of gas and the regionalisation of electricity, as growing characteristics of energy systems almost irrespective of (but even more vauable with) low carbon systems? PErhaps also given the mentions of security and resilience in this part of the report, take a quick look at the UK debates as covered in Newbery D. and Grubb M.(2015), Security of Supply, the Role of Interconnectors and Option Values: Insights from the GB Capacity Auction, Economics of Energy & Environmental Policy, Vol. 4, No. 2	Noted	Michael Grubb	UCL - Institute of Sustainable Resources	United Kingdom (of Great Britain and Northern Ireland)
46099	95	11	98	5	Significant regional aspects are heating, and seasonal variotion of solar, which can have significant influence on the type of the most viable solution for 100% RES system. For example https://www.nature.com/articles/s41467-019-08855-1	Accepted. We have included information on regional climate as a meaningful factor.	Neven Duic	University of Zagreb	Croatia

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
17027	95	23	95	23	The sentense "The answer depends to much on local circumstances and priorities," may be incorrect.	Accepted. We are working on the language as we adjust this section.	Qing YANG	Harvard University	China
4493	95	36	95	37	Integrated district or neighborhood approaches to buildings combining renewable energy and energy efficiency are useful to achieve zero-energy at the neighbourhood level	Noted	Leonardo Barreto	Austrian Energy Agency	Austria
17089	96	15	97	15	Reference is missing for picture and numbers in this Box.	Proper references are added for this section.	Kornelis Blok	Delft University of Technology	Netherlands
20429	96	16	96	24	cost optima for regional integration have been found for major regions all around the world, as summarised by Breyer et al. (https://www.iaee.org/eeep/article/305)	The reference is added to this section.	Christian Breyer	LUT University	Finland
18621	96	21	96	26	"weakly" -> "weekly" (twice)	Corrected.	Thomas Gibon	Luxembourg Institute of Science and Technology (LIST)	France
17029	96	24	96	25	Abbreviations in the legend should be stated in the caption.	Thanks. It is provided.	Qing YANG	Harvard University	China
8909	96	28	96	31	This statement has to be supported by reliable studies, and refernces must be given here.	A reference to this statement is added: NEWBERY, D., STRBAC, G., PUDJIANTO, D. & NOEL, P. 2013. Benefits of an integrated European Market.,"A report for Directorate General Energy European Commission" [Online]. London: Booz & Company,.	Michel SIMON	Vice Président SFENRAL	France
31847	97	1	97	1	It is not clear what the 10% is of	Thanks for pointing this out. To avoid confusion, this statement is updated.	Ashok Sreenivas	Prayas (Energy Group)	India
1543	97	4	97	7	#REF!	This statement is generalised and updated accrodingly.	Paul Vethman	PBL Netherlands Environmental Assessment Agency	Netherlands
4507	97	4	97	7	geopolitical risks of long-distance electricity transmission must be considered whene evaluating the feasibility of this option	This point is included to the paragraph :"Furthermore, west-east interconnection can enhance utilisation of renewable generation and further reduce cost of decarbonisation. Due to the different time zones, e.g., electricity from solar generation produced in Middle East (with higher capacity factors) could be used in Europe even after sunset, although geopolitical and socioeconomic challenges remain for international co-operation, as well as the techno-economic challenges associated with large-scale network expansion."	Leonardo Barreto	Austrian Energy Agency	Austria
8911	97	4	97	7	The project to develop solar electricity production plants in Sahara (Desertec) was mainly supported by Germany. It has been formally abandoned for economical reasons and geopolitical uncertainties in these african regions. To the best of my knowledge, there is no more plans in that direction.	Thanks for pointing this out. This statement is updated and generalised:"As hydrogen may have significant role in decarbonisation of the energy sector in future, the generated electricity by solar or wind can be used to generate hydrogen through electrolyses process, and then shipped to other locations. There is significant interest in producing hydrogen in the North Sea by offshore wind generation and also in the Middle East by solar generation. Hence, there is growing interest in infrastructure for transport of hydrogen over both short and long distances."	Michel SIMON	Vice Président SFENRAL	France
20431	97	4	97	7	the energy supply may be possible, but not much for a least cost solution as shown bei Bogdanov et al. (https://ieeexplore.ieee.org/document/7569508)	This statement is updated with the mentioned reference(s):"Further integration between Europe and MENA could also have significant mutual economic benefit and support increasing decarbonisation, potentially significantly contributing to a fully decarbonised system by 2030 (Bogdanov et al., 2016). This is further investigated in (Breyer et al., 2019)."	Christian Breyer	LUT University	Finland
11551	97	4		7	A reference for the given claim is missing. What about the electricity transmission costs? What about the politicl stability in the region?	Taken into account. The box has been substantially revised.	Arnulf JÄGER-WALDAU	European Commission, JRC	Italy

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
31685	97	6	97	7	I found this kind of suggestion quite inappropriate : are we really suggesting that European countries will somehow preempt some land in the Sahara desert to keep its way of life. Locals may like to use some of this electricity ? This kind of remark keeps telling that Western countries are trying to preserve their standard of living in the detriment of the rest of the world. We cannot suggest that it is a worldwide problem and that we have to work together to say that we will use their land for our needs.	Thanks for the suggestion. The text is updated and more generalised:"Climatic dipoles present both regionally and on continental scales could also help support diversification of renewable energy sources and mitigation of risk due to complementary weather and climatic phenomena across Northern, Southern Europe and beyond, and e.g. even more locally such as between the North and South of the UK (Dawkins, 2019). Further integration between Europe and MENA could also have significant mutual economic benefit and support increasing decarbonisation, potentially significantly contributing to a fully decarbonised system by 2030 (Bogdanov et al., 2016). This is further investigated in (Breyer et al., 2019). Furthermore, west-east interconnection can enhance utilisation of renewable generation and further reduce cost of decarbonisation. Due to the different time zones, e.g., electricity from solar generation produced in Middle East (with higher capacity factors) could be used in Europe even after sunset, although geopolitical and socioeconomic challenges remain for international co-operation, as well as the techno-economic challenges associated with large-scale network expansion. "	Alan BURLOT	Commissariat à l'énergie atomique et aux énergies alternatives	France
9997	97	16	97	19	Examples in the literature include: - Owusu, P. A., & Asumadu-Sarkodie, S. (2016). A review of renewable energy sources, sustainability issues and climate change mitigation. Cogent Engineering, 3(1), 1167990. - 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. - van Vliet, O., Krey, V., McCollum, D., Pachauri, S., Nagai, Y., Rao, S., & Riahi, K. (2012). Synergies in the Asian energy system: Climate change, energy security, energy access and air pollution. Energy Economics, 34, S470-S480. - Forouli, A., Doukas, H., Nikas, A., Sampedro, J., & Van de Ven, D. J. (2019). Identifying optimal technological portfolios for European power generation towards climate change mitigation: A robust portfolio analysis approach. Utilities Policy, 57, 33-42.	Accepted. We will bring in more linkages to broad sustainble development goals as we improve the feasibility assessment in the chapter.	Haris Doukas	School of Electrical and Computer Engineering, National Technical University of Athens	Greece
31849	97	17	97	19	Employment could also be added to this list.	Taken into account. We have included sustainable development as a possibility, which might include employment. But a broader treatment would be useful to revisit in the final draft depending on space. This would probably not address employment specifically, but more the economic development opportunities, some of which are already captured inthe topics of technology leadership and indigenous resources.	Ashok Sreenivas	Prayas (Energy Group)	India
34181	97	17	97	19	and energy price ? [suggestion ENSEEIHT INP]	Noted. Energy prices are perhaps embodied in the other factors listed, including resources and technology.	Antoine BONDUELLE	Climate Action Network France	France
16283	97	20			For Table 6.9, consider including a category called “geopolitical security” to be distinct from energy security, and which influences whether countries, for example, develop nuclear arms under a pretext of a new nuclear power program, as occurred in South Africa and Pakistan, and is currently occurring in Saudi Arabia.	Taken into account. The section has been substantially revised -- however we have not included a specific tratement of nuclear power.	Daniel Helman	College of Micronesia-FSM	Micronesia, Federated States of
10909	97	22	97	23	This is quite a crass generalisation and needs nuancing in the SOD.	Accepted.	Ian Bailey	University of Plymouth	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
31687	97	22	97	23	How can a phrase like this be written today ? This sentence is not even sourced. Do you have any evidence ? Businesses constantly tries to shape the demand, they creates new markets out of nowhere, they actively use marketing and commercials to push people to buy things they don't need in the first place. They managed to make new norms to change behaviour. This homo œconomicus vision of the society is so outdated and should not be present in such a report. This is a crucial point as it shapes the way we think society is built. Companies constantly tries to block new technologies or societal changes that might threaten their position. I insist, this is a crucial point. Thinking that the collection of individual decision is the base of policies does not allow to imagine large scale action taken from an elected-government. The current coronavirus crisis shows that sometimes decisions can and must be taken at the highest level to ensure that citizens act correctly, in their best interests.	Taken into account. The discussion has been substantially revised.	Alan BURLOT	Commissariat à l'énergie atomique et aux énergies alternatives	France
10913	97	22	98	5	The sub-section on societal preferences is very brief and should be a priority for deeper analysis in the SOD.	Taken into account. The discussion has been substantially revised, taking into account space limitations.	Ian Bailey	University of Plymouth	United Kingdom (of Great Britain and Northern Ireland)
16285	97	22	98	5	In the section on Societal Preferences, consider adding a brief treatment of organizational culture and the choices of militaries and governmental agencies in energy use and how those choices are distinct from consumer-based choices, and greatly influence GHG emissions as well.	Rejected. This is too much detail given the space and focus of the section.	Daniel Helman	College of Micronesia-FSM	Micronesia, Federated States of
44623	97	22	98	5	I think you should include - maybe right at the beginning - that 'responding to preferences' is not a straightforward thing, not even in democracies, where party-led governments are also led by ideologies, or the (perceived) preferences of certain voter groups relevant in electoral market considerations. Or, and that's a different angle, they might not respond by 'actions' but by 'talk' or 'decisions' that aim to highlight that political actors or bureaucracies "got the message" but then fail to deliver (or never even really tried). Some literature examples: on the electoral market orientation of politicians (see https://journals.sagepub.com/doi/10.1177/0038026117731658), the status quo orientation of senior public officials (see https://onlinelibrary.wiley.com/doi/abs/10.1002/wcc.305), path dependencies created by 'instrument constituencies' (see https://onlinelibrary.wiley.com/doi/abs/10.1111/gove.12179), or the benefits of deliberate inconsistencies between talk, decisions and actions in climate policy (see https://onlinelibrary.wiley.com/doi/abs/10.1002/wcc.305)	Taken into account. The discussion has been substantially revised, taking into account space limitations.	Oliver Geden	German Institute for International and Security Affairs	Germany
10911	97	27	97	29	It should be noted here that there are major obstacles to research on public accpetance of whole energy systems because of problems of visualisation what these energy systems would look like except in very broad outline terms. Additionally, research has repeatedly shown significant gaps in public acceptance of technologies in principle compared with acceptance in practice, so more abstract studies may have limited value.	Rejected. This is not the focus on the paragraph.	Ian Bailey	University of Plymouth	United Kingdom (of Great Britain and Northern Ireland)
34415	97	39	97	39	Please add: A general public survey in Germany has demonstrated that CCU was perceived significantly more positively when it was properly considered (Arning et al., 2019). (Arning et al. 2019, Energy Policy, 125, 235–249.)	Taken into account. The discussion has been substantially revised, taking into account space limitations.	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
44787	98	4	98	4	”While acknowledging that preferences can change over time.” The sentence is not complete.	Accepted	Daniel Westlén	Liberal party Swedish parliament	Sweden
44789	98	6	98	6	Sections 6.7 and 6.7.1 come before 6.6.4.1.	Editorial. The numbering should be corrected.	Daniel Westlén	Liberal party Swedish parliament	Sweden
17717	98	6	105	6	This section is valuable and speaks to my opeing Q about whether the chapter could be a bit more 'solution oriented'. At present it has a rather theoretical feel to it, but writing from the UK, we having been living. Authors could consider whether to say something this example of a country that has halved power sector CO2 emissions, mostly within the span of a decade (though of course, with a longer backgrond). Two main references that I know of: McMeekin, A., F. W. Geels, and M. Hodson, 2019: Mapping the winds of whole system reconfiguration: Analysing low-carbon transformations across production, distribution and consumption in the UK electricity system (1990–2016). Res. Policy, 48, 1216–1231, https://doi.org/10.1016/j.respol.2018.12.007.; and my own evaluation of the EMR evolution and lessons with David Newbery: 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. Also maybe relevant: Trutnevyte, E., 2016: Does cost optimization approximate the real-world energy transition? Energy, 26 106, 182–193, https://doi.org/10.1016/j.energy.2016.03.038.	Noted. Example of a country that has halved power sector CO2 emissions should be in 6.3 Recent Energy System Trends and Developments.	Michael Grubb	UCL - Institute of Sustainable Resources	

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
15789	98	13	98	13	The EN ROADS simulator by Climate Interactive which can help people visualize the energy transition from a high carbon to a low carbon economy. The online EN ROADS simulator is not as much sofisticated as a IAM, but it can help diferent "agents", that is a) individuals and households, b) NGOs, social movements and c) the private sector understand which mitigation strategies are available and get a feeling of their impact on climate mitigation. Focusing on the the available mitigation strategies and their projected impact with purpose of generating more awareness on what is needed to fully address climate change. Climate Interactive has made available the simulator at https://www.climateinteractive.org/tools/en-roads/ , with a list of key possible available mitigation strategies and climate actions that show in real time the projected temperatures created by aplying mitigation strategies the climate actions in a worldwide scale. Here is a link to their latest article, Rooney-Varga, J. N., Kapmeier, F., Sterman, J. D., Jones, A. P., Putko, M., Rath, K., The Climate Action Simulator, Simulation & Gaming, https://journals.sagepub.com/doi/full/10.1177/1046878119890643 A word of caution: this EN ROADS simulator is not an IAM, it is just an easy to use simulator for general public use in order to foster and to create more awareness on posible mitigation strategies that could lead to a 1.5 scenario. For example, it has been used by politicians, media, students, and public in general, as stated in Climate Interactive's page "A wide range of people have used En-ROADS, including members of the U.S. Congress, HSBC bank, the Hewlett Foundation, local community groups, the UN Secretary-General's Office, university professors around the world, leading science educator Bill Nye, and many others." at: https://www.climateinteractive.org/tools/en-roads/	Noted. The Climate Action Simulation -EN ROADS - is a communication tool help people understand the complexity of the interactions between the climate and energy systems, rather than scientific assessment.	EDUARDO PEDRO FRACASSI	ITBA Instituto Tecnologico de Buenos Aires	Argentina
1547	98	14	98	14	The numbering of sub-paragraphs is not correct throughout paragraph 6.7.1	Editorial. The numbering should be corrected.	Paul Vethman	PBL Netherlands Environmental Assessment Agency	
11731	98	14	98	14	Comment: sub-heading has the wrong numbering. Occurs elsewhere in section 6.7.1	Editorial. The numbering should be corrected.	Paul Brockway	University of Leeds	
16461	98	14	98	14	The section 6.6.4.1 doesn't discuss regional CO2. Please change the title. It should also make clear that the CO2 emisisons trajectories in Figure 6.34 are globally cost-effective scenarios. BTW, is industrial CO2 included here?	Accepted. Discussion on the regional CO2 trajectories from energy sector will be added based on the AR6 scenario database. Should be clarified whether industrial CO2 emissions are included or not. (or delete "regional" elements)	Xunzhang Pan	School of Economics and Management, China University of Petroleum, Beijing 102249, China	
20433	98	14	99	18	this section does not refelect literature well and requires major revision. Several global 100% renewalbes scenarios exist which are all ignored in this section. This documents a weak literature knowledge. All these articles/ scenarios are summarised by Breyer et al. (https://www.iaee.org/eeep/article/305) - all scenarios are at least until 2050 and all end with 100% renewables. - a broad discussion on the topic is also provided by Hansen et al. (https://www.sciencedirect.com/science/article/pii/S0360544219304967)	Taken into account. Although major revision is not needed, but will touch 100% renewables scenario in this section, if appropriate.	Christian Breyer	LUT University	
25085	98	14	99	18	Section 6.6.4.1 relates to emissions at a global and regional level, but there is no explicit analysis on regional emissions	Accepted. Discussion on the regional CO2 trajectories from energy sector will be added based on the AR6 scenario database.	Eleni Kaditi	Organization of the Petroleum Exporting Countries (OPEC)	
6467	98	14	105	7	The sub(sub)sections should 6.7....	Editorial. The numbering should be corrected.	Paul Neetzow	Humboldt-Universität zu Berlin	
37867	98	14			The subsection numbering 6.6.4.1. and following subsections is inconsistent with the higher level section 6.7.1 / 6.7	Editorial. The numbering should be corrected.	Gunnar Luderer	Potsdam Instittute for Climate Impact Research	
39687	98	14			It is confusing that the text is about the SSPs and corresponding baseline scenarios while the corresponding figure 6.34 is about C1-C7.	Taken into account. The text is about the SSPs and figure 6.34 are discussed in a different context, but the text will be revised for clear linkage with the figure.	Simon Davidsson Kurland	Chalmers University of Technology	
20783	98		99		Due to the uncertainty of temperature rising caused by GHG emissions, the carbon budget may be discussed when talking about the scenarios characterised by temperature change.	Noted. Carbon budget is discussed in another chapter.	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	
17031	99	1	99	1	The meaning of the right line in the figure is not clear. And the sentence "energy sector emissions from CO2" may be not correct.	Accepted. Legend of the figure will be revised	Qing YANG	Harvard University	
17033	99	15	99	18	I suggest that the situation in 2019 should be added as the emission in 2019 may exceed 33 Gt.	Noted. The emissions date in 2019 is not available yet.	Qing YANG	Harvard University	
20435	99	19	100	33	Several global scenarios exist showing 100% renewables by 2050 - one is even in the AR6 database. this section does not refelect literature well and requires major revision. Several global 100% renewalbes scenarios exist which are all ignored in this section. This documents a weak literature knowledge. All these articles/ scenarios are summarised by Breyer et al. (https://www.iaee.org/eeep/article/305) - all scenarios are at least until 2050 and all end with 100% renewables.	Taken into account. Although major revision is not needed, but 100% renewables scenarios are referred in this section.	Christian Breyer	LUT University	

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
44625	99	20	99	22	The number is higher than 70 now, but it's hard to keep track, and some of these announcements are not overly credible. I'd focus on UNFCCC parties here, and again, their targets/pledges are mostly about GHGs, not CO2 only, which creates a slight tension with the geophysical requirement of reaching net zero CO2 in order to stabilize the climate - but that's an issue that needs to be dealt with more thoroughly in ch1 and 3	Taken into account. This issue is mainly dealt with in Chapter1 and 4 as the reviewer suggested.	Oliver Geden	German Institute for International and Security Affairs	
41355	99	21	99	21	Re "...have announced long-term net-zero emissions targets": Check if related but different concepts are used; cabon neutrality, climate neutrality, GHG balance	Taken into account. Text will be revised to be more precisely specified.	Jan Fuglestvedt	CICERO	
41357	99	25	99	26	You may refer to table 2.4 in SR1.5 here (or in first para on page 100)	Noted. Table 2.4 of SR15 is "Emissions in 2030, 2050 and 2100 in 1.5°C and 2°C scenario classes and absolute annual rates of change between 2010–2030, 2020–2030 and 2030–2050, respectively." Relevant topic should be dealt with based on the AR6 database.	Jan Fuglestvedt	CICERO	
44627	100	4	100	10	These ranges (from Rogelj 2015) are based on the (considerably smaller) AR5 budget and should be updated	Noted. Check AR6 database.	Oliver Geden	German Institute for International and Security Affairs	
41353	100	17	100	17	"Climate metrics" is also used for other climate variables (such a global mean temperature) and should be replaced my "emission metrics"	Noted. "Climate metrics" cover broader concept than "emission metrics"	Jan Fuglestvedt	CICERO	
41359	100	17	100	19	Regarding how timing depends on emission metric: I suggest adding "GHG" after "net zero"	Accepted. Text should be revised as per reviewer's suggestion.	Jan Fuglestvedt	CICERO	
26071	100	17	100	23	You may wish to elaborate for some readers why the GWP/GTP time horizon matters, just one or two explanatory sentences. Many readers are students who use the IPCC reports to establish their base knowledge. The following paragraph on discount rates is a good model.	Accepted. Text will be elaborated more as per reviewer's suggestion.	CHRISTOPHER BATAILLE	IDDRI.ORG/SIMON FRASER UNVIERSITY	
37433	100	17	100	23	This paragraph discusses the timing of net-zero 'economy wide' emissions (e.g., as discussed in Figure 2 of Fuglesvedt et al 2018) of all GHGs, where every other paragraph in this section describes CO2 emissions from the energy system. This discussion is only relevant when equating other GHGs to a common metric with CO2 and is confusing in an otherwise complete conversation regarding net-zero CO2 emissions. Please remove or relate directly to other finidings within WG3, e.g., Chapter 3.4.1.	Noted. It is true that this paragraph discusses the timing of net-zero 'economy wide' emissions of all GHGs, but it is mentioned in relation to the CO2 emissions from the energy system. This paragraph may be rephrased in an easily understood manner.	Michiel Schaeffer	Climate Analytics	
37435	100	17	100	23	Further, the consistency of the Paris Agreement can be made an issue if interpretations are taken that divert from the approach taken in the AR5 on which the Agreement is based. If the Paris Agreement is interpreted in the metrics based on the Paris Agreement (temperature as well as GWP), Article 2 and 4 provide a fully consistent set. See Schleussner, C.-F., Nauels, A., Schaeffer, M., Hare, W., & Rogelj, J. (2019). Inconsistencies when applying novel metrics for emissions accounting to the Paris Agreement. Environmental Research Letters, (December 2016), 0–22. https://doi.org/10.1088/1748-9326/ab56e7	Accepted. Referred to the suggested reference.	Michiel Schaeffer	Climate Analytics	
26317	100	20	100	23	Tanaka and O'Neill (2018, 10.1038/s41558-018-0097-x), which tested GWP100, GWP20, and GTP100 in the context of the Paris Agreement, is also relevant to the discussion here. This work imposed the net zero GHG target using GWP100, GWP20, and GTP100 in a dynamic cost-effective setting and looked into the temperature outcome. The paper shows that, when such emission target needs to be met by 2060, GWP100 implies declining temperatures after peaking around 2C. GTP100 leads to stable temperatures around 2C. GWP20 makes the net zero goal unachievable under the assumptions in the study. This paragraph should provide a link to Box 2.2, which discusses metric-related issues in details.	Accepted. Referred to the suggested reference.	Tanaka Katsumasa	Laboratoire des Sciences du Climat et de l'Environnement (LSCE), CEA, FRANCE; National Institute for Environmental Studies (NIES), JAPAN	
41361	100	21	100	22	Again, I suggest adding "GHG" after "net zero" in both cases in this sentence.	Accepted. Text should be revised as per reviewer's suggestion.	Jan Fuglestvedt	CICERO	
24677	100	24	100	33	Discount rate has a direct impact on the anticipation of investors. Recongizing that the present trend shows that investors (private or public ones) do not take sufficiently into account the future constraint could lead to lock-in effects which will strongly increase the future costs of emission reductions.	Noted. This comment should be covered in Section 6.7.4.	Florent LE STRAT	ELECTRICTE DE FRANCE	
16287	100	34			In Section 6.6.4.3 Energy transition strategies, adding a subsection or brief treatment of the potential of drilling infrastructure from the oil/gas sector being used to develop wells and reservoirs for hot dry rock geothermal energy. Briefly, hot dry rock geothermal does not require endemic water resources nor is it restricted to tectonically active regions. Instead drilling is done with deep wells and heat extraction for electricity generation uses a closed-loop system typically with either water or CO2 as the heat transfer fluid. The development of appropriate drilling technology to develop hot dry rock geothermal wells and reservoirs is a current area of investment by, e.g. oil companies in Texas, and may provide an avenue for rapid energy transition. Oil and gas companies would have an incentive to transition to being primarily geothermal energy companies in some scenarios.	Rejected. Need scientific literature to validate the comments and show suggested technologies have siginficant impacts on emissions reduction.	Daniel Helman	College of Micronesia-FSM	

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
27975	100	35	100	39	IPCC states, "Limiting temperature change requires a fundamental transformation of the global energy system, and there is no single technological route to achieve the targets (Clarke et al. 2014; Rogelj et al. 2018a). Supply-side low-carbon technology options include a rapid shift away from fossil-fuel toward large scale low carbon energy supplies, such as renewables and nuclear power, and deployment of carbon dioxide removal (CDR) technologies." This statement is not substantiated by facts on the ground. As found in Sekera, J., and A. Lichtenberger, The carbon capture conundrum: Public need versus private gain, A public policy perspective on carbon dioxide capture, 2020, https://drive.google.com/file/d/1K-BIULOUtfSs5LVCS9ONaDzq7jeFmO-b/view and in 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 , synthetic CDR technologies (those aside from natural reforestation) are opportunity costs. Similarly, nuclear will play little if any role in future decarbonization. Since 2006, nuclear power production worldwide has declined, not increased. This can be seen from the data here: https://www.world-nuclear.org/information-library/current-and-future-generation/nuclear-power-in-the-world-today.aspx . Given this negative growth rate and the long time-lag between planning and operation of new nuclear (10-19 years) and its high cost, this begs the question as to why nuclear is even being considered in this document as an option. Given that we need 80% reduction in emissions by 2030 to avoid 1.5 C warming, not a single new nuclear plant planned today can be installed before 2030. Thus, scenarios that claim that CDR or nuclear can help solve global warming are misleading and non-credible. Thus, there is only one way to solve global warming, and that is with the combination of renewables, storage, transmission, and demand response while simultaneously eliminating nonenergy emissions from biomass burning, nitrous oxide, methane leaks, and halogen leaks.	Rejected. The combination of renewables, storage, transmission, and demand response could be one of the solutions, but there are significant amount of literatures that present the other approaches to reduce emissions significantly. We don't limit technical option a priori for the sake of scientific accuracy.	Mark Jacobson	Stanford University	
17035	100	35	100	44	I suggest that this paragraph should also include discussion about the heat sector especially in the demand side, as heating emits a huge amount of carbon dioxide too.	Taken into account. Heat is covered in 6.7.1.3.3 Demand side in the context of building sector decarbonization.	Qing YANG	Harvard University	
12393	100	38	100	39	Please consider to also include CCS in this sentence, for instance like the following: "....., deployment of carbondioxide removal technologies (CDR) and CCS for the remaining fossil fuel."	Accepted. Will include CCUS in the paragraph.	Maria Malene Kvalevåg	Norwegian Environment Agency	
34417	100	39	100	39	Please add "and CCU" after CDR.	Accepted. Will include CCUS in the paragraph.	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	
36523	100	46	100	47	Low-carbon technologies is a key language but there seems to be no consensus about its definition. Sometime we observed big gap among the requirement for green bond, green finance etc. This language is used at P109 and P119 and original literature of these refence are different. It is better to introduce each definition to avoid confusion.	Taken into account. Examples of low carbon technologies are clarified in the text.	Takashi Hongo	Mitsui & Co. Global Strategic Studies Institute	
35607	100				low carbon energy supply is below 20% - of what?	Accepted. Clarify it.	Robert Gross	Imperial College and UKERC	
28899	101	1	102	1	The box 6.19 is very hard to understand, perhaps because the layout is messy. But anyway, I couldn't understand what is the figure and graph want to tell the reader about? The font also too small, and not explanation about x-axis and y-axis	Accepted. Box 6.19 will be revised in a way that is consistent with illustrative pathways of AR6	Marissa Malahayati	National Institute for Environmental Studies	
34419	101	5	101	5	Key technologies contributing to emission reduction do not only depend on scenarios, they also depend on the ability of the models to take them into account. To date, the IAM's have failed in simulating the complexity of CDR and as well on the different CCU options to realize net zero or negative CO2 emissions (e.g. Detz and Zwaan, 2019). Consequently, CCU technologies are unfairly considered to have limited and predominantly indirect abatement potential and are not discussed as mitigation options in the different IPCC reports. As stated in the Annex C of this first order draft, IAM's are missing important dynamics, e.g. with regard to carbon dioxide removal (Smith et al. 2016), rapid technological progress in the renewable energy sector (Creutzig et al. 2017), actor heterogeneity, and distributional impacts of climate change and climate policy. This has given rise to criticism that IAM's lack credibility in set of crucial assumptions, among which stands out the availability of carbon dioxide removal technologies (Bednar et al. 2019; Anderson and Peters 2016). This recognized failure of the IAM's to represent specific technologies should not prevent the integration of updated scientific discussions on all existing important technologies to mitigate climate change. It should also be noted that Energy System Models (EMS) are able to simulate the major CCU routes and other specific technologies and therefore a discussion on EMS and on their key results should be added in the report (Ram et al., 2019 EWG&LUT, 2019: Global Energy System Based On 100% Renewable Energy, Energy Watch Group & LUT Universityeir key results should be added in the report (e.g.Ram et al., 2019, Krey et al., 2019).(Krey et al., 2019, Energy, 172, 1254-1267/Detz and Zwaan, 2019, Energy Policy, 133, 110938/ Creutzig et al. 2017, GCB, Bioenergy./ Bednar et al. 2019, Nat. Commun., 10, 1783/Anderson and Peters, 2016, Science, 354, 182–183/ Smith et al. 2016, Nature Climate Change, 6, 42-50	Accepted. Text is revised and suggested studies are referred.	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
38011	101	6	101	11	The 'Renewable Driven Transition (Sustainability) illustrative energy transition, should in the descriptor, last sentence reaed 'Battery AND HYROPOWER energy storage systems that provide flexivility services to the grid'.	Accepted. Change to "Energy storage" instead of "Battery energy storage", as suggested below.	Atle Harby	SINTEF Energy Research	
43685	101	6			The illustrative scenarios are interesting. The mixed-technology one has >15Gt NETs per year. That appears to be very high for me, for a scenario that is seeking middle ground. Maybe this is simply a bias of the scenarios that find it easier to implement BECCS than demand-side or RE options?	Accepted. Box 6.19 will be revised in a way that is consistent with illustrative pathways of AR6	Felix Creutzig	MCC Berlin	
2351	101	12	101	12	Figure 2: Instead of "Battery energy storage", more general "Energy storage", that includes also other technologies.	Accepted. Change to "Energy storage" instead of "Battery energy storage", as suggested.	Dieter Boer	Universitat Rovira i Virgili	
18743	101	12	102	1	The axes of the charts need units and also scaled to be read	Accepted. Add units to the axes.	Grant Wilson	University of Birmingham	
20785	101		102		The figures in Box 6.19 need to be explained about the axis, the meaning of the colors	Accepted. Add legend and units to the axes.	ZHENG LYU (Former family name LU)	Shanghai Advanced Research Institute, Chinese Academy of Sciences	
45471	101				Box 6.1: the figures are not clear - there are no legends or units; the accompanying text adds little.	Accepted. Add legend and units to the axes.	Girija Parthasarathy	Thermo King	
16463	102	5	102	6	What's the share for the NDC scenario? The NDC scenario is more likely to happen than the 2C/1.5C scenario in the coming decade.	Rejected. The focus of this section is energy transition toward carbon neutral energy system, not highly probable scenario, such as NDC scenario.	Xunzhang Pan	School of Economics and Management, China University of Petroleum, Beijing 102249, China	
16529	102	5	102	6	What's the share for the NDC scenario?	Rejected. The focus of this section is energy transition toward carbon neutral energy system, not highly probable scenario, such as NDC scenario.	Lining WANG	Economics and Technology Research Institute, CNPC	
16469	102	8	102	11	Should be "due to" and "utilization of".More importantly, the role and the development of oil and gas depend on mitigation scenarios and climate goals, see Pan et al. (2020; Analysis of China’s oil and gas consumption under different scenarios toward 2050: An integrated modeling; doi: https://doi.org/10.1016/j.energy.2020.116991).	Partially accepted. The text is corrected. Note that the focus of this section is energy transition toward carbon neutral energy system in the global context, not probable scenarios for a specific country.	Xunzhang Pan	School of Economics and Management, China University of Petroleum, Beijing 102249, China	
37437	102	10	102	11	It is not particularly useful to point out a specific study without providing context as to how this study fits into the overall assessed literature. Please either provide such context or remove the statement.	Accepted. The sentence is deleted.	Michiel Schaeffer	Climate Analytics	
34421	102	12	102	12	please replace sentence by:" including renewables, CCU technologies and nuclear power,"	Rejected. CCU technologies are not non-fossil low-carbon energy sources.	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	
23921	102	15	102	16	In the industry sector biomass might play a role in the high temperature sectors, due to their difficult decarbonisation.	Noted. This comment is consistent with the sentence.	Stefan Majer	German Biomass Research Centre - DBFZ	
18745	102	19	102	19	because electricity can be generated in a carbon free manner with diverse technology options, including renewables, nucelar, fossil fuels with CCS' - stating that fossil fuels with CCS is carbon free is at best a low-carbon option, not a zero carbon option. This is true of all the other technologies too when life cycle emissions are considered.	Accepted. Use appropriate technical term.	Grant Wilson	University of Birmingham	
34423	102	19	102	19	please replace sentence by: "with diverse technology options, including renewables, CCU, nuclear, fossil fuels with CCS" (e.g. Farfan et al., 2019, J. Clean Prod., 217, 821-835./ Ram et al., 2019 EWG&LUT, 2019: Global Energy System Based On 100% Renewable Energy, Energy Watch Group & LUT University.)	Rejected. The contribution of CCU is relatively minor.	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	
35473	102	19	102	19	misspelling of "nuclear"	Editorial. Should be corrected.	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	
18747	102	25	102	25	Electricity is clearly a major and growing energy vector in zero-carbon energy systems however, this section reads as a highly electrocentric view of the future. A personal view is that other low/zero carbon energy vectors are required to underpin the electrical system - but this is rather overlooked in the text so far. Non-fossil fuels will become increasingly important as a means to help decarbonise energy systems. Batteries are ill matched to TWhs of storage over longer periods - and the world needs TWhs of storage for continued trade and security of supply. I wonder if another heading on low-carbon or zero-carbon fuels would be suitable to include as well as electricity? These could both be under a broader heading of low-carbon zero carbon energy vectors? The UK's committee on climate change net-zero report in 2019 looks at low-carbon energy vectors - not just electricity.	Noted. This subsection highlights the role of electricity. Other low/zero carbon energy vectors are covered in other subsection.	Grant Wilson	University of Birmingham	

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
8913	102	25	103	25	I suggest that in tis paragrah, you emphasize the urgent need to achieve rapidly actual reduction of GHG emissions, referring to the time life of CO2 in the atmosphere. To reach such aim, energy policies in all countries should support all low-carbon energies, available today at industrial stages. R&D wil bring new sources of carbon free électricity in the coming years or decades and must be encouraged. However,rise of electricity consumption and reduction of CO2 emissions must become a reality in the short term, and thus the developmment of all low carbon sources is the only option : Wind and solar where apropriate, hydro, nuclear in countries able to use that technology, geothermal, etc... This need a very large effort of information of the public, allowing everyone to understand the resaons of the choices made.	Noted. Policy and public choice are out of scope of this subsection.	Michel SIMON	Vice Président SFENRAL	
20437	102	25	103	25	major revision is required for this section due to poor literature knowledge. All references are from the IAM world, docuemeting that ALL articles from the ESM world are simply ignored, while several 100% renewable studies on global level existing, all covering the full electricity system and several covering all energy sectors. Such literature gaps MUST be fixed. Overview to 100% renewable ESM studies can be found here in Breyer et al. (https://www.iaee.org/eeep/article/305) presented in a simple table with references to all articles	Taken into account. Suggested literature is referred, and 100% RE scenario is added in the second last paragraph of this section.	Christian Breyer	LUT University	
25087	102	25	103	25	Analysis to also refer to issues related to energy access, affordability and reliability	Noted. Energy access, affordability and reliability are discussed in section 6.7.7	Eleni Kaditi	Organization of the Petroleum Exporting Countries (OPEC)	
43581	102	26	102	33	the statement is also supported by Ram et al. (http://energywatchgroup.org/wp-content/uploads/EWG_LUT_100RE_All_Sectors_Global_Report_2019.pdf) for a least cost energy system with zero GHG emissions in 2050 and massive electrification	Noted. Suggested report is a non-peer reviewed source.	Christian Breyer	LUT University	
36525	102	34	102	38	Is “Electricity demand is increased to be quadrupled to quintuple in 2100” line with “1200 EJ” scenario? In page 103 L27-30, two scenarios, say 1200EJ or 550 EJ as the demand in 2100, are described and consistency is needed. Total demand is very important in relation to lock-in effect, which is analyzed at 6.7.3.2. If supply capacity is bigger than demand, capacity will not be used. Fossil fuel power generation which needs fuel supply is less competitive than renewable, such as PV or wind power. Scenario of total demand provides big impacts on decision making for new capacity.	Rejected. 1200EJ and 550 EJ are about final energy demand, which is different from electricity demand.	Takashi Hongo	Mitsui & Co. Global Strategic Studies Institute	
20525	103	7	103	25	more ambitious renewable scenarios are ignored in this section and shall be added. Important it is not the target to show 100% VRE scenarios but 100% RE which is something different, since some hydropower and bioenergy is available. Bogdanov et al. (https://www.nature.com/articles/s41467-019-08855-1) show a least cost solution for 100% RE power sector; Ram et al. (http://energywatchgroup.org/wp-content/uploads/EWG_LUT_100RE_All_Sectors_Global_Report_2019.pdf) show a least cost solution for all energy sectors - all in full hourly resolution. An overview on all global 100% renewable energy scenarios is provided by Breyer et al. (https://www.iaee.org/eeep/article/305), while Hansen et al. (https://www.sciencedirect.com/science/article/pii/S0360544219304967) provides an overview on all deteceted 180 articles on 100% renewables by end of 2018.	Taken into account. Suggested literature is referred, and 100% RE scenario is added in the second last paragraph of this section.	Christian Breyer	LUT University	
37871	103	7			There is a strong debate about the adequacy of the IAM assumptions on renewable electricity technologies, particular photovoltaics. IAMs may have underestimated (and some continue to underestimate) technology learning and cost degressions in these technologies, leading to an undertestimation of their role in future electricity systems. Key references: Creutzig, Felix, Peter Agoston, Jan Christoph Goldschmidt, Gunnar Luderer, Gregory Nemet, und Robert C. Pietzcker. „The Underestimated Potential of Solar Energy to Mitigate Climate Change“. Nature Energy 2, Nr. 9 (September 2017): 17140. https://doi.org/10.1038/nenergy.2017.140. Krey, Volker, Fei Guo, Peter Kolp, Wenji Zhou, Roberto Schaeffer, Aayushi Awasthy, Christoph Bertram, u. a. „Looking under the hood: A comparison of techno-economic assumptions across national and global integrated assessment models“. Energy, 21. Dezember 2018. https://doi.org/10.1016/j.energy.2018.12.131. Pietzcker, Robert C., Falko Ueckerdt, Samuel Carrara, Harmen Sytze de Boer, Jacques Després, Shinichiro Fujimori, Nils Johnson, u. a. „System integration of wind and solar power in integrated assessment models: A cross-model evaluation of new approaches“. Energy Economics 64 (1. Mai 2017): 583–99. https://doi.org/10.1016/j.eneco.2016.11.018.	Accepted. Referred to sussested literature and revised the text.	Gunnar Luderer	Potsdam Instittute for Climate Impact Research	
26073	103	10	103	13	Some arguably false statements "electrification potentials are low for transport and industry" are made here without substantiation. It looks like personal transport at least can be largely be eventually electrified (directly through battery EVs, or indirectly through fuel cells, or combinations thereof), light industry can be largely electrified via heat pumps, electric boiler boost, etc., and heavy industry partially electrified directly or through hydrogen as the intermediate energy carrier. I suggest you moderate and substantiate these statements or remove them.	Taken into account. This comment is relevant to page 104, not 103. Inserted "relatively"	CHRISTOPHER BATAILLE	IDDRI.ORG/SIMON FRASER UNVIERSITY	

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
18749	103	11	103	11	their quantity and quality differ vastly at the regional level' - this could perhaps be rephrased or removed. It would seems that with fossil fuel or nuclear resources there is also a regional disparity	Accepted. Deleted.	Grant Wilson	University of Birmingham	
37869	103	15			"they are not possible to produce electricity simultaneously with demand". Better reformulate to "they are not dispatachable "	Accepted. Rephrase this sentence.	Gunnar Luderer	Potsdam Insttitute for Climate Impact Research	
34425	103	18	103	19	Please add this paragraph: CCU technologies can play a key role in bringing more flexibility to the grid in allowing the storage and transport of energy..(e.g. Ram et al., 2019 EWG&LUT, 2019: Global Energy System Based On 100% Renewable Energy, Energy Watch Group & LUT University./Farfan et al., 2019, J. Clean Prod., 217, 821-835.)	Rejected. CCU contribution is relatively minor compared to battery technologies.	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	
32267	103	20	103	25	It could be precised that the role of flexible production means to stabilize the network will become greater and greater. Today the 2 proeminent low-carbon flexible electricity productions are hydro and nuclear.	Noted. The point of comment is not clear.	Jean-Guy Devezeaux de Lavergne	Commissariat à l'Energie Atomique et aux Energies Alternatives	
18751	103	25	103	25	Battery energy storage systems that provide flexibility services to the grid are promising options to integrate higher shares of VRE' - this is true for shorter timeframes - but for amounts of energy that need to be stored longer than a few days and at TWh scales - batteries are not a promising option. Low-carbon fuels (synthetic fuels) are needed. This is a similar point to point 44 above	Accepted. Will be rephrased. "Battery" has been removed.	Grant Wilson	University of Birmingham	
31851	103	26	103	26	Suggest that the demand section (currently 6.6.4.3.3) comes before the supply section (currently 6.6.4.3.1) because, as discussed in earlier chapters, demand management can play an important role in mitigation and because the purpose of supply is to meet a given demand.	Rejected. Logical flow of this section follows the flow of energy from supply to demand.	Ashok Sreenivas	Prayas (Energy Group)	
46101	103	26	105	6	Power-to-heat missing again? The most important flexibility option for integration of VRES.	Accepted. Deal with power to heat in this section.	Neven Duic	University of Zagreb	
31853	103	29	103	30	It is not clear if the 550 EJ per year in the latter half of the century is for the 2 deg C scenario.	Rejected. This sentence is for SSP baseline scenarios, not for the 2C scenario.	Ashok Sreenivas	Prayas (Energy Group)	
31689	103	46	104	1	This kind of statement is, sorry to be direct, quite ridiculous : we have never stopped increasing our energy consumptions. This statement is not sourced and it is of a fundamental importance as so many peoples (citizens, politics, etc.) think that we might achieve this. The rebound effect is everywhere. We never had economical gross without an increase of energy consumption. The countries which think they succeeded in this have just relocate the energy consumption somewhere else on Earth. This kind of thinking is disastrous as it does not take into account the global material consumption of land or mineral matter. The least that should be done here is to prevent that this thinking might not be sustainable.	Partially accepted. Add source of this information.	Alan BURLOT	Commissariat à l'énergie atomique et aux énergies alternatives	
15719	103	46	104	9	In this section on demand adjustment, arguably, material consumption and use efficiency can also have a substantial impact on energy demand and GHG emissions. The IEA 2019 report on material efficiency, grounded on the various works of Allwood and Cullen et al, indicates that cement (6.4% of current GHG emissions) and steel (8.3%) demand could potentially be reduced by 26 & 40% if materially efficient design were engaged. More broadly, other sources indicate that building and infrastructure design, cementious material substitution, and better material production could allow reductions in cement and steel use of 25-75% depending on the application. Not all of this will be achievable, but there is a large scope for improvement. Sources: International Energy Agency, 2019a. Material efficiency in clean energy transitions [WWW Document]. Paris, France. https://doi.org/10.1787/aeaaccd8-en; Bataille, C. 2019. Physical and policy pathways to net-zero emissions industry. WIREs Climate Change. 2020;11:e633. https://doi.org/10.1002/wcc.633; Bataille, C. 2019. Low and zero emissions in the steel and cement industries: Barriers, technologies and policies. OECD Green Growth and Sustainable Development Forum. https://www.oecd-ilibrary.org/environment/low-and-zero-emissions-in-the-steel-and-cement-industries_5ccf8e33-en; Allwood, J. and J. Cullen (2015), Sustainable materials without the hot air: making buildings, vehicles and products efficiently and with less new material., UIT Cambridge Limited; Allwood, J. and J. Cullen (2012), Sustainable Materials: With both eyes open, Cambridge, UK: UIT Cambridge.	Noted. Material efficiency is touched in the second last paragraph of this section.	CHRISTOPHER BATAILLE	IDDRI.ORG/SIMON FRASER UNVIERSITY	
17037	104	1	104	4	I suggest that the reason for the energy demand decline than current size should be explained.	Noted. It is discussed in the second and third paragraph of this subsection.	Qing YANG	Harvard University	
45077	104	4	104	5	The role of urban areas, including in demand side transformations, may be given relevant referrals (Chapter 5 and 8).	Noted. The role of urban areas is briefly touched in 6.7.1.3; "development of efficient urban infrastructure". The details are discussed in chapter 8.	Siir Kilkis	The Scientific and Technological Research Council of Turkey	
18753	104	12	104	13	need to be reduced by fuel switching to biofuels ...' - there are a number of options e.g. hydrogen, ammonia, synthetic methane. Biomass is only one of these. Consider amending the sentence to open it up to other energy vectors too.	Accepted. Revised this sentence to include more technological options.	Grant Wilson	University of Birmingham	

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
5657	104	14	104	18	The following two references provide peer-reviewed evidence that the combination of energy efficiency improvements and electrification of end-uses is an optimal pathway to decarbonize the buildings sector. This additional evidence would be helpful, since the only citation there now is to one IEA report. Furthermore, these two references make another important point: that efficiency improvements to reduce building energy use reduce the cost of climate policy, so the two policy interventions should be interpreted as complements rather than substitutes. Eom, J., Clarke, L., Kim, S.H., Kyle, P., Patel, P., 2012. China's building energy demand: Long-term implications from a detailed assessment. Energy 46, 405-419. Leibowicz, B.D., Lanham, C.M., Brozynski, M.T., Vázquez-Canteli, J.R., Castillo Castejón, N., Nagy, Z., 2018. Optimal decarbonization pathways for urban residential building energy services. Applied Energy 230, 1311-1325.	Accepted. Cite the suggested literature.	Benjamin Leibowicz	The University of Texas at Austin	
11113	104	14	104	25	Add examples of policies that enhance electrification and avoid carbon lock-ins in building sector. Eg, restriction of connecting gas pipelines into new buildings (Berkeley, CA)	Taken into account. Main focus of this section puts on technology, rather than policy.	Midori Sasaki	industrial organization	
44323	104	15	104	16	renovation of existing buildings includes thermal insulation, air tightness, heat recovery and very efficient technial equipment, this is also valid for new buildoings. Both renovation and new buildings shall aim at Net Zero Energy Buildings.	Accepted. Replaced "renovating" with "improving"	BERTOLDI PAOLO	European Commission	
26075	104	18	104	19	There is a broad literature on why consumers may not behave "optimallly" from an economic point of view regarding energy efficiency investement; inforamtion costs, capital constraints, option value, capital expenditure risk averaion, etc. See Jaffe & Stavins 1994, or Borenstein 2015. Sources: Jaffe, A. B., & Stavins, R. N. (1994). The energy paradox and the diffusion of conservation technology. Resource and Energy Economics, 16(2), 91-122.; Borenstein, S. (2015). A microeconomic framework for evaluating energy efficiency rebound and some implications. The Energy Journal, 36(1).	Accepted. Add reference.	CHRISTOPHER BATAILLE	IDDRI.ORG/SIMON FRASER UNVIERSITY	
20439	104	26	104	35	weak literature knowledge is also documented for the transport sector which can achieve zero GHG emissions by 2050, as shown by several ESM research teams around the world, whereas not a single IAM team showed comparable pathways, such a weak literature knowledge needs to be overcome. All is tabulated in Tab. 27 in Khalili et al. (https://www.mdpi.com/1996-1073/12/20/3870) - see all scenarios with zero fossil fuels in 2050.	Accepted. Text is revised and suggested literature is referred to.	Christian Breyer	LUT University	
34697	104	26	104	35	A 100% renewable transport msut undertake also changes in logisitcs of cargo and the impacts on commuting in the cties and inter-cities, the impact on air tranport for a zero-carbon transport imply a reduction of the aviation fleet (Antonio García-Olivares, Jordi Solé, Oleg Osychenko, Transportation in a 100% renewable energy system,Energy Conversion and Management,Volume 158,2018,Pages 266-285,ISSN 0196-8904,https://doi.org/10.1016/j.enconman.2017.12.053.)	Accepted. Text is revised and suggested literature is referred to.	Jordi Solé-Ollé	Spanish National Research Council (CSIC)	
34183	104	28	104	29	The weight of cars is also a key component https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5415645/ [suggestion ENSEEIHT INP]	Taken into account. Add "the weight of cars" in the sentence, if appropriate.	Antoine BONDUELLE	Climate Action Network France	
15721	104	36	104	46	This section on industry seems a bit limited and out of date; the literature on decarbonization of industry has evolved a lot. It's not all about replacing high temperature heat from fossil fuels. Taking steel as an example, there are at least five ways to decarbonize the sector: CCS; hydrogen direct reduced iron followed by an electric arc furnace; aqeous or molten oxide electrolysis + EAF; biochar; and more, better quality recycling with an EAF. The cheapest way to reduce cement emissions is to make better mixed concrete with a wider size range of aggregates with less cement, and then with cementious material subsitution to reduce Portland Cement needs, then CCS for process emissions (e..g the LEILAC project) and then combustion emissions, and then maybe alternative cement chemistries. But this is the energy chapter, so maybe you don't need these levels of detail. Sources: Bataille, C., Åhman, M., Fischedick, M., Lechtenböhmer, S., Neuhoff, K., Nilsson L.J., Solano-Rodriquez, B., Denis-Ryan, A., Steibert, S., Waisman, H., Sartor, O., and Rahbar, S. 2018. A review of technology and policy deep decarbonization pathway options for making energy intensive industry production consistent with the Paris Agreement. Journal of Cleaner Production. 187:960-973. doi.org/10.1016/j.jclepro.2018.03.107; Bataille, C. 2019. Physical and policy pathways to net-zero emissions industry. WIREs Climate Change. 2020;11:e633. https://doi.org/10.1002/wcc.633; Bataille, C. 2019. Low and zero emissions in the steel and cement industries: Barriers, technologies and policies. OECD Green Growth and Sustainable Development Forum. https://www.oecd-ilibrary.org/environment/low-and-zero-emissions-in-the-steel-and-cement-industries_5ccf8e33-en	Accepted. Updated this section with the suggested literature.	CHRISTOPHER BATAILLE	IDDRI.ORG/SIMON FRASER UNVIERSITY	
42031	104	36			In view of the electrification issues discussed in this paragraph, a potential improvement is to include the following mitigation possibilities: use of power supplies with power electronics for efficient use of energy (high effciency converters, power factor correction, active filtering -very important for electric arc furnaces), control systems or methods for efficient use of energy, electronic drive motor controls, district level solutions (local energy networks) or on-site combined power, heat or cool generation or distribution (combined heat and power supply).	Noted. Some of suggested technology options, such as power to heat in other paragraph in which they fit better into the context	Francisco Javier Hurtado Albir	European Patent Office	

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
12395	104	38	104	38	Please consider to include both CCS and CCUS	Rejected. CCUS includes both CCS and CCU.	Maria Malene Kvalevåg	Norwegian Environment Agency	
34427	104	38	104	38	CCUS should be splitted into CCU and CCS.	Rejected. CCUS includes both CCS and CCU.	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	
20441	104	38			the misleading wording of CCUS has to be fixed, see literature for a clear separation: 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).	Rejected. CCUS cover both CCS and CCU.	Christian Breyer	LUT University	
42033	104	46			Together with the reference to general industry, something should be said for agroalimentary industry, with mitigation pssibilities in the use of renewable energies for irrigation or powering greenhouses (for instance) and energy savig measures in irrigation (by motor control), reduction of fuel consumption, combined machines (seeding combined with fertilizing)	Noted. This should be dealt with in Chapter 7.	Francisco Javier Hurtado Albir	European Patent Office	
16465	104	47	105	6	The impacts of limiting warming to 1.5C rather than 2C are very important information. Can we discuss in more details here? How can we decarbonize energy supply at a more rapid pace? What are the changes to primary mix and electricity mix? What are these further efforts in the industry, transport and building sectors? What happened to the requirement of CDR? I know some papers discuss this, e.g. those by Joeri Rogelj. Please further investigate the literature. Can we highlight some key characteristics or compare some key indicators when moving from 2C to 1.5C here?	Noted. The differences between 1.5C and 2C are scattered across the section.	Xunzhang Pan	School of Economics and Management, China University of Petroleum, Beijing 102249, China	
32479	105	7	105	7	There's an error in the document that brings in section 6.6.4.1 (and more) and section 6.7 doesn't continue for many pages.	Editorial. The numbering should be corrected.	Durwood Zaelke	Institute for Governance & Sustainable Development	
20443	105	7	105	24	The role of BECCS vs DACCS is not yet well described, while the ramp up of DACCS could be much faster. More insights can be found in Breyer et al. (https://www.cell.com/joule/fulltext/S2542-4351(19)30413-1) and Creutzig et al. (https://pubs.rsc.org/en/Content/ArticleLanding/2019/EE/C8EE03682A)	Noted. Suggested literatures are referred to.	Christian Breyer	LUT University	
17245	105	7	106	37	Section 6.7.1 is missing.	Editorial. The numbering should be corrected.	Joachim Rock	Thuenen-Institute of Forest Ecosystems	
32481	105	8	105	24	It would be useful to move up and emphasize the point that BECCS is prevalent in IAMs because they have not traditionally included other means of CDR, while also noting the strong evidence that BECCS is not carbon negative on relevant time scale of the next couple of decades. BECCS is not carbon negative in the near-term because bioenergy leaves a carbon deficit for several decades to a century—far longer than the window of a decade or two available for slowing feedbacks and avoiding hitting the 1.5C guardrail. See, e.g., IPCC AR5 WG III (2014) 11.13.4 GHG emission estimates of bioenergy production systems ("The combustion of biomass generates gross GHG emissions roughly equivalent to the combustion of fossil fuels. If bioenergy production is to generate a net reduction in emissions, it must do so by offsetting those emissions through increased net carbon uptake of biota and soils…Hence, the total climate forcing of bioenergy depends on feedstock, site-specific climate and ecosystems, management conditions, production pathways, end use, and on the interdependencies with energy and land markets…For example, in the specific case of existing forests that may continue to grow if not used for bioenergy, some studies employing counterfactual baselines show that forest bioenergy systems can temporarily have higher cumulative CO2 emissions than a fossil reference system (for a time period ranging from a few decades up to several centuries"). Subsequent analysis since AR5 further strengthens the case that bioenergy is not carbon neutral in the critical next decade or two. Danielle Venton, Core Concept: Can bioenergy with carbon capture and storage make an impact?, PNAS (2016); 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.	Taken into account. Some of referred literature, such as Creutzig et al. 2019, assesses not only BECCS but also DACCS.	Durwood Zaelke	Institute for Governance & Sustainable Development	

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
32481					Comment continued: 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."). Also note that reductions of atmospheric methane should be listed along with other CDR strategies. Jackson R.B., Solomon E.I., Canadell J.G., Cargnello M., & Field C.B., Methane removal and atmospheric restoration, NATURE SUSTAINABILITY 2, 436–438 (2019) ("In contrast to negative emissions scenarios for CO2 that typically assume hundreds of billions of tonnes removed over decades and do not restore the atmosphere to preindustrial levels, methane concentrations could be restored to ~750 ppb by removing ~3.2 of the 5.3 Gt of CH4 currently in the atmosphere. Rather than capturing and storing the methane, the 3.2 Gt of CH4 could be oxidized to CO2, a thermodynamically favourable reaction …. In total, the reaction would yield 8.2 additional Gt of atmospheric CO2, equivalent to a few months of current industrial CO2 emissions, but it would eliminate approximately one sixth of total radiative forcing. As a result, methane removal or conversion would strongly complement current CO2 and CH4 emissions-reduction activities. The reduction in short-term warming, attributable to methane's high radiative forcing and relatively short lifetime, would also provide more time to adapt to warming from long-lived greenhouse gases such as CO2 and N2O.").		Durwood Zaelke	Institute for Governance & Sustainable Development	
44629	105	8	105	24	You should also refer to the CDR sections of ch7 and ch12 here	Accepted. Both chapters are referred to.	Oliver Geden	German Institute for International and Security Affairs	
104	105	9	105	10	How can a energy system become carbon negative through the use of CDR? An exampled may be cited here for clarity.	Taken into account. Section 6.6.4.4 is restructured based on the comments in a way that focus on several key topics without expanding discussion.	Govindasamy Bala	Indian Institute of Science	
18755	105	13	105	14	Even in pathways with limited BECCS, there remain certain amount of BECCS, implying that the development of CDR ...' - the point about BECCS seems to be repeated in this sentence.	Accepted. Part of the sentence was deleted.	Grant Wilson	University of Birmingham	
106	105	15	105	18	Chapter 5 of WG1 report should be cited and linked here.	Noted. Focus of Chapter5 of WG1 is Biogeochemical responses to CDR, which is different from the context of this section.	Govindasamy Bala	Indian Institute of Science	
41381	105	16	105	19	biochar is listed among "CDR technologies outside the energy sector" . This is not correct, as biochar is produced from biomass with substantive bioenergy co-production. See Homagain et al 2015 (cited in this chapter), Gitau et al 2019, doi.org/10.3390/en12224285, Azzi et al 2019 doi: 10.1021/acs.est.9b01615, Schmidt et al 2018 doi: 10.1111/gcbb.12553	Accepted. The sentence is revised.	Cecilia Sundberg	Swedish University of Agricultural Sciences	
30027	105	17	105	18	Isn't enhanced weathering connected to the energy system as well? Grinding rock is highly energy intensive.	Accepted. The sentence is revised.	Merk Christine	Kiel Institute for the World Economy	

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
34429	105	33	105	33	Not only DACCS should be discussed, but DACCU as well. CCU is a key parameter for the viability of DAC. In the case of CCU, added value can be positive as a result of the cost savings from fossil raw material reduction. If the capture costs can be minimized, CO2 can be given a value and transformed from a liability into an asset (Bruhn et al., 2016, Krey et al., 2019). The existing literature shows that the current benefits of CCU are numerous (VITO, 2018). CCU can: • Decrease CO2 emissions at relatively short-term • Replace fossil or biobased feedstock • Defossilize the process industry and transportation sector • Store energy • Contribute to a circular economy • Create a revenue stream for CO2 abatement from fossil fuel use based on consumer demand for CO2-containing products. • Be an alternative for CCS • Improve Energy security • Make use of specific attributes of CO2 in commercially competitive applications • Remediate inorganic wastes from industrial processes • Sequestrate significant quantities of CO2 in building materials • Provide revenues to fund (partially) CCS projects • Reduce the complexity of chemical reaction pathways • Control the cost for the supply of fuels • Relocalize the energy supply (e.g.Bruhn et al., 2016, Environmental Science & Policy, 60, 38–43./ Krey et al., 2019, Energy, 172, 1254-1267./VITO, 2018 (Miet van Dael), Market Study Report CCU, Flemish Institute for Technological Research NV./IEAGHG, 2019a: Putting CO2 to Use – Creating value from emissions, International Energy Agency)	Accepted. The sentence is modified.	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	
20335	105	33	105	41	latest literature on DAC and DACCS should be incorporated for a more balanced discussion. Breyer et al. (https://www.cell.com/joule/fulltext/S2542-4351(19)30413-1) and Fasihi et al. (https://www.sciencedirect.com/science/article/pii/S0959652619307772) broadly discuss the techno-economics of DAC and DACCS which differ from literature, which is also related to the fact that most academic literature is based on the high-temperature (Carbon Engineering) route, while most companies in the field - also with most real plants in the field - go for the low-temperature route, which allows a much better energy efficiency and performance. Major revision of this section is required.	Taken into account. Section 6.6.4.4 is restructured based on the comments in a way that focus on several key topics without expanding discussion.	Christian Breyer	LUT University	
20445	105	33	105	41	information on low-cost DACCS is missing in this chapter, while published by Breyer et al.: https://www.cell.com/joule/fulltext/S2542-4351(19)30413-1 ; https://link.springer.com/article/10.1007/s11027-019-9847-y ; https://www.sciencedirect.com/science/article/pii/S0959652619307772	Taken into account. Section 6.6.4.4 is restructured based on the comments in a way that focus on several key topics without expanding discussion.	Christian Breyer	LUT University	
32483	105	33	105	41	Direct Air Capture also has the capacity to produce liquid fuels. See, e.g., David Keith et al., A Process for Capturing CO2 from the Atmosphere, Joule (June 2018) ("An industrial process for large-scale capture of atmospheric CO2 (DAC) serves two roles. First, as a source of CO2 for making carbon-neutral hydrocarbon fuels, enabling carbon-free energy to be converted into high-energy-density fuels. Solar fuels, for example, may be produced at high-insolation low-cost locations from DAC-CO2 and electrolytic hydrogen using gas-to-liquids technology enabling decarbonization of difficult-to-electrify sectors such as aviation. And second, DAC with CO2 sequestration allows carbon removal.").	Taken into account. This section is streamlined and focuses on several key topics, rather than expanding discussion.	Durwood Zaelke	Institute for Governance & Sustainable Development	
42393	105	33	105	41	Like BECC DAC also has business cases if the Co2 is not stored	Taken into account. This section is streamlined and focuses on several key topics, rather than expanding discussion.	Christoph Beuttler	Climeworks AG, Risk Dialogue Foundation	
9999	105	34	105	35	A good reference for this, here: - Realmonte, G., Drouet, L., Gambhir, A., Glynn, J., Hawkes, A., Köberle, A. C., & Tavoni, M. (2019). An inter-model assessment of the role of direct air capture in deep mitigation pathways. Nature communications, 10(1), 1-12.	Accepted. Suggested literature is referred to.	Haris Doukas	School of Electrical and Computer Engineering, National Technical University of Athens	
26225	105	37			land requirement may be a constraint (al least in certain regions) also for direct air capture, not only for beccs. "According to Climeworks' estimations, around 2,000 km2 of non-arable land would be needed to remove 1 gigaton of CO2 net from the atmosphere, including the required renewable energy production (...) The footprint of the actual DAC plants would cover just 62 km2." Source: Christoph Beuttler, Louise Charles and Jan Wurzbacher (2019) The Role of Direct Air Capture in Mitigation of Anthropogenic Greenhouse Gas Emissions	Noted. This part is deleted.	Sara Budinis	International Energy Agency	

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32485	105	42	105	47	In addition to not being carbon negative, large-scale BECCS could put significant strains on global freshwater use, land-system change, biosphere integrity, and biogeochemical flows. Vera Heck et al., Biomass-based negative emissions difficult to reconcile with planetary boundaries, Nature Climate Change (January 2018) ("[W]hile large-scale BECCS is intended to lower the pressure on the [planetary boundaries (PB)] for climate change, it would most likely steer the Earth system closer to the PB for freshwater use and lead to further transgression of the PBs for land-system change, biosphere integrity and biogeochemical flows."). It is important to note that BECCS is not carbon negative in the near-term because bioenergy leaves a carbon deficit for several decades to a century—far longer than the window of a decade or two available for slowing feedbacks and avoiding crashing through the 1.5C guardrail. See, e.g., IPCC AR5 WG III (2014) 11.13.4 GHG emission estimates of bioenergy production systems ("The combustion of biomass generates gross GHG emissions roughly equivalent to the combustion of fossil fuels. If bioenergy production is to generate a net reduction in emissions, it must do so by offsetting those emissions through increased net carbon uptake of biota and soils…Hence, the total climate forcing of bioenergy depends on feedstock, site-specific climate and ecosystems, management conditions, production pathways, end use, and on the interdependencies with energy and land markets…For example, in the specific case of existing forests that may continue to grow if not used for bioenergy, some studies employing counterfactual baselines show that forest bioenergy systems can temporarily have higher cumulative CO2 emissions than a fossil reference system (for a time period ranging from a few decades up to several centuries"). Subsequent analysis since AR5 further strengthens the case that bioenergy is not carbon neutral in the critical next decade or two. Danielle Venton, Core Concept: Can bioenergy with carbon capture and storage make an impact?, PNAS (2016); 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.	Noted. Suggested literature has been referred to in the FOD.	Durwood Zaelke	Institute for Governance & Sustainable Development	
32485					Comment continued: 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."). In addition, the CCS part of BECCS has not been demonstrated at scale or at acceptable cost, nor has it won over the support it would need from the public. See Gregory Nemet et al., Negative emissions—Part 3: Innovation and upscaling, Environ. Res. Lett. (May 2018); European Academies Science Advisory Council, Negative emission technologies: What role in meeting Paris Agreement targets? (Feb 2018) ("CCS plans in Europe have been shelved so that whatever experience is being gained globally is outside Europe. The loss in momentum in implementing CCS technologies not only has serious implications for mitigation pathways, but also one of the most commonly cited NETs [negative emissions technologies] (BECCS) assumes the availability of cost effective 'off-the shelf' CCS, while another (direct air capture) relies on the widespread availability of CO2 storage. At present, economic incentives for deploying CCS are inadequate (whether through the very low carbon price or targeted government support), while those for NET development are lacking."); Andersen & Peters, The Trouble with Negative Emissions, Science (Oct 2016). One study estimates that current rate of increase in CCS is 100 times lower than needed to meet the 2C target. See Haszeldine et al. (April 2018), Negative emissions technologies and carbon capture and storage to achieve the Paris Agreement commitments, Philosophical Transactions of the Royal Society. Thus, BECCS should not be presented as a viable CDR strategy.		Durwood Zaelke	Institute for Governance & Sustainable Development	
44631	105	42	105	47	Maybe add some non-quantitative analyses on these issues, because these brought the debate really forward, e.g. https://www.tandfonline.com/doi/full/10.1080/14693062.2017.1346498 or https://link.springer.com/article/10.1007/s10584-016-1770-6 or https://link.springer.com/article/10.1007/s10784-017-9382-9	Accepted. One of the suggested literature is referred to.	Oliver Geden	German Institute for International and Security Affairs	

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
34431	106	1	106	6	The discussion here is quite weak and misses references. And here again, CCU is not considered in the discussion while it is considered in numerous publications as key mitigation options: The capture and conversion of CO2 into valuable products require the use of important renewable energy sources, an aspect that is often considered as a drawback to use these technologies. However, the prices of the different renewable energy options as well as an adequate evaluation of the future evolution of these prices (especially the cost of the solar energy) is crucial to assess the viability and climate mitigation potential of CCU technologies (Creutzig et al., 2017, Breyer et al., 2019, Haegel et al., 2019, Vartiainen et al., 2019, Krey et al., 2019). Even if no exhaustive quantification exists today on the mitigation potential of CCU technologies, the key role of this concept should be considered as one building block in a portfolio of mitigation measures (e.g. GCI, 2016, Grüber et al., 2018, IEAGHG, 2019b, Detz and Zwaan, 2019). CO2 utilization will contribute to curbing CO2 emissions with an estimated potential impact of gigatons equivalent CO2 emissions, similar or even superior to the impact of CCS and biofuels, but with a lower cost for society (Ampelli et al., 2015). 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 (GCI, 2016). Moreover, the key role of CCU as a vector to move away from fossil fuel resources and the potential move to a CO2 circular economy should be recognized and discussed adequately in the IPCC AR6 (e.g. Bruhn et al., 2016, Daggash et al., 2018). (Daggash et al., 2018, Sustainable Energy Fuels, 2, 1153-1169./Bruhn et al., 2016, Environmental Science & Policy, 60, 38–43./GCI, 2016: Global Roadmap Study of CO2U Technologies, LUX Research & Global CO2 Initiative./Ampelli et al., 2015: CO2 utilization: an enabling element to move to a resource and energy-efficient chemical and fuel production, Phil.Trans.R.Soc.A, 373./Breyer et al., 2019, Joule, 3, 2053-2057./Creutzig et al. 2017, GCB, Bioenergy./ Haegel et al., 2019, Science, 364, 836-838./ Grüber et al, 2018: A low energy demand scenario for meeting the 1.5 C target and sustainable development goals without negative emission technologies', Nature Energy, 3, 6./Krey et al., 2019, Energy, 172, 1254-1267./ Vartiainen et al., 2019, Progress in Photovoltaics, Wiley, 1-15/IEAGHG, 2019b: Exploring Clean Energy Pathways: the role of energy storage, International Energy Agency./Detz and Zwaan, 2019, Energy Policy, 133, 110938./ GCI, 2016: Global Roadmap Study of CO2U Technologies, LUX Research & Global CO2 Initiative./Hepburn et al., 2019: The technological and economic prospects for CO2 utilization and removal, 575, 87-97)	Parially accepted, referring to some of suggested literature. This section is streamlined.	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	
43733	106	19	106	26	The question of forward looking indicators is very important in terms of the ability to step in and take remedial action if policies, for example, are not delivering against assumptions. One area is forward-looking indicators for actual investment: policies that anticipate a 'market response' through investment into renewables or the diversity of 'energy transition' technologies need to understand whether these assumptions are on track for being met. I have done some work on this, or at least raised the issue. A grey literature reference raising the issue of forward-looking metrics for investment is section 1.4 page 5 in the Discussion paper "'Investment Confidence' for Governments: Integrating investment into climate-related policymaking", foot of homepage: https://www.climate-kic.org/insights/investment-confidence-for-governments-ensuring-climate-policy-attracts-capital/). A general comment is that most investment or investment flows numbers are inherently backward looking, or modelled.	Accepted. Investment related indicator is added.	Kirsty Hamilton	Chatham House (Associate Fellow, unpaid)	
18757	106	28	106	28	In addition to the statistical yearbook (annual values) there is another element of data that underpins a shift to more renewable systems. Due to the variable nature inherent of variable renewable resouces, it is important that countries are able to understand different energy flows at a minimum of a daily level (in additiona to monthly, quarterly or annual). This is important to allow the data to be collected - and this process should be started from 2020-2025 to allow greater understanding of the 'Where are we starting from?' question framed by the Talanoa Dialogue. Some text in this regard in the box would seem to be helpful, as it would raise the point about daily statistics (hourly statistics would be even better - but daily data would seem to be a good place to start for many countries who do not currently have this level of data). As mentioned in earlier comments - I am unsure about whether a reviewer should mention ones own work - but this is an increasingly important issue about having the right type of data to be able to provide greater certainty about the choices of future energy systems. Some of these points were raised in a paper I published in 2016 - https://doi.org/10.3389/fenrg.2016.00033 . The UK is pretty well served with data in this regard - the issue is for many other countries to start to create systems to collect this type of data - so that they are in a better position in future to evidence the shift to more renewable primary energy sources. The overall point is that in addition to the annual metrics, they should also look to understand more granular data too (e.g. daily)	Noted. It would be useful to have daily or hourly statistics, but difficult to collect the same level of data across the world for the sake of globalstocktake.	Grant Wilson	University of Birmingham	
16289	106	37			In Section 6.7.2 Investments in Technology and Infrastructure, consider adding a treatment of military and governmental agencies driving transition by investing in technology and infrastructure, for accuracy and clarity.	Rejected. Need scientific literature that supports the role of military and governmental agency in driving transition in the context of energy systems.	Daniel Helman	College of Micronesia-FSM	Micronesia, Federated States of
11553	106	41	107	37	A critial analysis and review of direct and indirect subsidies for fossil energy is missing. E.g. IMF papers	Rejected. Subsidies are discussed in other sections.	Arnulf JÄGER-WALDAU	European Commission, JRC	Italy
5699	106	41	109	21	This or another relevant section should note recent announcements of major institutional investors (Blackrock, Goldman Sachs) to make climate more central to their investment strategies.	Noted. That kind of information will be covered in the finance chapter (Chapter15).	Seth Seth Dunn	General Electric	United States of America

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
26077	106	42	107	2	This paragraph would read more easily if the summed trillions of investment added to the total 2018 amount, or were put in a context that was clearly comparable.	Noted.	CHRISTOPHER BATAILLE	IDDRI.ORG/SIMON FRASER UNVIERSITY	Canada
3013	106				Box 6-20: The global stocktake under the Paris agreement would likely be a sesnsitive issue. The assessed energy system transitions in AR6 will be usefull but nontheless the whole AR6 assessment will be only one component of the stocktake. So probably and in the spirit of being less prescriptive it may be wiser t not emphasize the stocktake too much here.	Noted. Paid attention not to be policy prescriptive, but to be policy relevant.	Mustafa Babiker	Aramco	Saudi Arabia
20447	107	20	107	28	the statements in this section do not reflect the body of literature and thus requires a major revision. There are several studies for the global sector which have ZERO investments for fossil CCS technologies, they are all summarised in the article of Breyer et al. (https://www.iaee.org/eeep/article/305), while Bogdanov et al. (https://www.nature.com/articles/s41467-019-08855-1) is even published on Nature level. In addition, Ram et al. (http://energywatchgroup.org/wp-content/uploads/EWG_LUT_100RE_All_Sectors_Global_Report_2019.pdf) show that zero CCS investments are needed for the entire energy system to reach a zero GHG emission system, in a least cost case, for full hourly resolution and for less system cost that of today (this scenario is even part of AR6 scenario database). Such relevant findings have to be reflected to represent the state-of-the-art in the field!	Noted. Focus of this section is investment in energy system, rather than pickin up some specific technologies. There is a counter argument against to 100% RE scenario or no CCS scenario, See Clack, Christopher TM, et al. "Evaluation of a proposal for reliable low-cost grid power with 100% wind, water, and solar." Proceedings of the National Academy of Sciences 114.26 (2017): 6722-6727. Some argue that 100% RE scenarios are not supported by adequate and realistic analysis and do not provide a reliable guide to whether and at what cost such a transition might be achieved. Consider an appropriate balance between these two diverse views.	Christian Breyer	LUT University	Finland
34433	107	25	107	25	CCUS should be replaced by CCS	Rejected. CCUS includes CCS.	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
10915	107		109		Text in this section would benefit from careful proof-reading and editing.	Editorial.	Ian Bailey	University of Plymouth	United Kingdom (of Great Britain and Northern Ireland)
17039	108	1	108	1	Essential explanations should be added in figure 6.36, for instance, the meaning of the diamond.	Accepted. Add explanations.	Qing YANG	Harvard University	China
45385	108	3	108	5	Is the declining ability to get funding for carbon-based (particularly coal) energy generation infrastrcution addressed? May be unfolding too fast to be explored in an academic study. Most mahjor insurers have pulled back fundamentally impacting the risk profile of certain assets, and major investmetn funds are as well due to increased risk combined with lower returns. There is an excess of capital seekign to invest in the safest clean energy investmetns (soalr and wind farms) and returnsare coreespondingly conservative.	Noted. That kind of information will be covered in the finance chapter (Chapter15).	Deborah Knuckey	Published energy journalist plus consultant for renewable energy development and finance companies through Kiterocket	United States of America
43737	108	3	109	21	Cross reference with p.115 line 6 about the 'Designing policy for avoiding lock-in needs to account for the role of time;' There is a critical timing and sequencing of policy and regulatory decisions re tackling barriers *at the right level of detail* for investors (and other actors).	Noted. This section mainly focus on the scale of investment and p.115 discusses on an enabling environment for investment.	Kirsty Hamilton	Chatham House (Associate Fellow, unpaid)	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
43735	108	4	117	29	This comment starts with a specific paragraph but raises a key area for further work and is relevant for Ch6 and Ch15 in particular (I have reviewed Chs 6, 15 and 16) [I don't know how to move this up into general comments]. What is good in this para is the linkage point between the investment needs and the need to tackle barriers (line 4) to low carbon investment. Policy and regulatory-linked barriers are a key area, yet there is not a direct linkage between issues raised in pages 108/109) and section 6.7.5 Policy and Governance (page 117). I note that although the the final sentence on page 108 suggests the issue is 'shifting' existing capital investment, this needs qualified by the fact that there is substantial existing investor interest in renewables and 'energy transition' technologies like battery storage and the businesses and services that are part of that transition. The issue that is often articulated by investors as a lack of 'good projects' to invest in (sometimes refered to by investors as the project pipeline which means investors are generally looking for not just a single investment but a pipeline of further investments that have related characteristics - in the same market. A simple example would be 'is there going to be another renewable energy auction' - when and for how much capacity or budget?). This regulatory issues as countries move through the energy transition are very important, notwithstanding technology cost reductions, or even where there is an LCOE based assessment that renweables are cheaper - if specific risks are high then certain pools of capital may not be able to invest. It is important to understand the linkage between the development of 'good' projects/the project pipeline (including on- and off-grid) and the policy and regulatory environment in its broadest sense (policy can include government decisions on public finance and 'de-risking' financial instruments or tools). See for example 'Developing Robust Project Pipelines for Low Carbon Infrastructure", OECD, November 2018, from http://www.oecd.org/environment/developing-robust-project-pipelines-for-low-carbon-infrastructure-9789264307827-en.htm (I was an advisor and reviewer for this report), and a useful review of project development facilities in ODI's "Finding the Pipeline", Nov 2016. A further qualification is that the world of 'projects' and 'project finance' as a common model for renewable energy deployment is itself changing as the energy transition precipitates different models and importantly scale of opportunity to the delivery of energy services (for example smaller projects or projects with multiple potential revenue streams such as battery storage). I have done evidence-based work with finance practitioners (debt and equity) with early grey literature papers on 'investment grade' policy For example: - 'Unlocking Finance for Clean Energy: the need for 'Investment Grade' Policy', Chatham House Programme Paper, December 2009 (https://www.chathamhouse.org/publications/papers/view/109193); "Scaling up Renewable Energy in Developing Countries, Finance and Investor Perspectives", Chatham House Programme Paper, April 2010; 'Finance Guide for Policymakers', August 2016, published by Bloomberg New Energy Finance with Chatham House, Frankfurt School, FS-UNEP Collaborating Centre (see Section 2.2, page 56 'Policy and Regulatory Risk in Depth' . [http://about.bnef.com/white-papers/finance-guide-policy-makers/]. I have a 2019 grey literature paper 'Investment Confidence for Governments - ensuring climate policy attracts capital" - this is about the	Noted. Points made by the reviewers are relevant mainly for Chapter 15.	Kirsty Hamilton	Chatham House (Associate Fellow, unpaid)	United Kingdom (of Great Britain and Northern Ireland)
28901	109	1	109	1	No x-axis and y-axis for R5REF, R5ASIA, and R5MAF. Also the x-axis needs to be a little bit to the left.	Accepted. Add explanations.	Marissa Malahayati	National Institute for Environmental Studies	Japan
2161	109	4	109	5	This sentence needs to be revised.	Accepted. Revise the sentence.	Amy Townsend-Small	University of Cincinnati	United States of America
18759	109	5	109	5	doesn't' too informal - consider 'does not'	Accepted. Revise the sentence.	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
36713	109	11	109	11	The reference of Spencer et al. 2018 from page 17 lines 4 and 25 is missing	Rejected. The suggested study is not relevant to the sentence.	Pietro Altermatt	R&D Center of Trinasolar	Germany
2353	110	1	110	1	Text in figures too small, better put figures one below the other.	Accepted. Make the text bigger.	Dieter Boer	Universitat Rovira i Virgili	Spain
28903	110	1	110	1	Please remove the "category_name" below your figure, make the text bigger too, your reader can't read it well.	Accepted. Make the text bigger.	Marissa Malahayati	National Institute for Environmental Studies	Japan
6053	110	6	110	6	Error, should be 'renewable energy' in 'Switching to fossil fuels reduces air pollution and has positive health effects.'	Accepted. Revise the sentence.	SAIK PENG, CASEY NGO	R-SYNC TECHNICAL RESOURCES SDN. BHD.	Malaysia
17041	110	6	110	6	I suggest that the "Switching to fossil fuels reduces air pollution and has positive health effects" should be further explained. Why dose the switching to fossil fuels reduces air pollution and has positive health effects?	Accepted. Revise the sentence.	Qing YANG	Harvard University	China
10917	110	6	110	6	Surely it is switching from fossil fuels, not to them.	Accepted. Revise the sentence.	Ian Bailey	University of Plymouth	United Kingdom (of Great Britain and Northern Ireland)
13491	110	6	110	6	Isn't it rather "switching from fossil fuel"?	Accepted. Revise the sentence.	Sophie Szopa	Commissariat à l'Energie Atomique et aux Energies Alternatives	France
22911	110	6	110	6	The original sentence: "Switching to fossil fuels reduces air pollution and has positive health effects." seems a bit confusing, that preposition "to" should be "from" in my thinking, that is, the whole sentence should look like this: "Switching from fossil fuels reduces air pollution and has positive health effects."	Accepted. Revise the sentence.	Xiusheng Zhao	Tsinghua University	China
18027	110	6	110	6	I think it mean to say "from" not "to" , and "may have positive health effects"	Accepted. Revise the sentence.	Tim Dixon	IEAGHG	United Kingdom (of Great Britain and Northern Ireland)
31855	110	6	110	6	"Switching away from fossil fuels" and not "Switching to fossil fuels"!	Accepted. Revise the sentence.	Ashok Sreenivas	Prayas (Energy Group)	India

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
3015	110	9	110	22	Should also mention that shifting away from fossil fuel investments via policy and finance tools could run the risk of inadequate investment in fossil fuel supplies needed to meet demand during the transition.	Noted. Need scientific literature that supports the reviewer's comment.	Mustafa Babiker	Aramco	Saudi Arabia
18029	110	13	110	13	Unles fitted with CCS, see Budinis (2017) Energy Procedia V114 p7504 and IEAGHG report 2016-05	Noted. May include relevant findings, if appropriate.	Tim Dixon	IEAGHG	United Kingdom (of Great Britain and Northern Ireland)
26079	110	23	110	24	Unsubstantiated statement and faulty logic: "Jobs could shift from emission-intensive sectors, such as mining, chemical, steel, and cement, to low-carbon industry." The steel, cement, chemicals and mining sectors are essential for building transit systems, electric and hydrogen fueling networks, etc. One cannot generally substitute bankers or other services workes for steel. If these sectors' GHG intensities cannot be reduced to very low levels (unlikely, talk to the Industry chapter people) and we must make do with much less materials there will be a substantial macroeconomic penalty. It is more likley efforts will be made to reduce material intensity, reduce industry GHG production emissions intensity, and possibly compensate remaining emissions with negative emissions than dramatically reduce our use of steel, cement, chemicals, etc.	Accepted. Text is revised.	CHRISTOPHER BATAILLE	IDDRI.ORG/SIMON FRASER UNVIERSITY	Canada
11555	110	23		31	Various publications have shown the potential of a decarbonised energy system tpo provide more jobs than the existing ones. E.g. IRENA, https://www.sciencedirect.com/science/article/pii/S0040162518314112 , etc.	Noted. If renewable energy sector requires the larger number of people to produce the same amount of energy with fossil fuel sector, it implies a low energy productivity. It is not a good sign in terms of economic efficiency.	Arnulf JÄGER-WALDAU	European Commission, JRC	Italy
31857	110	24	110	26	Moreover, it is not just about the number of jobs that renewables can support. Will it be able to support similar jobs as in the fossil fuel industry and if not, then what measures need to be taken to support those who will be losers due to the transition is the interesting question.	Noted. The quality of jobs or measures to support job reallocations are out of scope of this section.	Ashok Sreenivas	Prayas (Energy Group)	India
11557	110	33		34	Not only the scocial acceptance of these technologies, but the investment costs, building duration and availability of technology and raw material is crucial.	Noted. The points made by the reviewers are taken into account in most IAMS.	Arnulf JÄGER-WALDAU	European Commission, JRC	Italy
25089	110	36	110	36	Delete "green"	Accepted. Delete "green"	Eleni Kaditi	Organization of the Petroleum Exporting Countries (OPEC)	Austria
35209	111	1	111	35	There is a substantial section on lock-in in Chapter 13 on p. 23, 80 etc. This and the Chapter 13 material needs to be made consistent with one another.	Accepted. Added to text.	Llewelyn Hughes	Australian National University	Australia
3017	111	1	115	25	Section 6.7.3: The focus on lock-in mainly limited to carbon intensive technologies and production processes. There is nothing said about the risk of lock-in for new low-carbon technologies which can occur given the state of development for some of these technologies and the possible limits to their scalability.	Noted. These impact could not be covered because of limited literature.	Mustafa Babiker	Aramco	Saudi Arabia
10001	111	7	111	8	Table 6.10: It is a figure instead of a table, the source has been ommitted (Kotilainen et al., 2019). The source has been incorrectly cited as (Kotilainen et al., 2020) both in-text and in references: - Kotilainen, K., Aalto, P., Valta, J., Rautiainen, A., Kojo, M., & Sovacool, B. K. (2019). From path dependence to policy mixes for Nordic electric mobility: Lessons for accelerating future transport transitions. Policy Sciences, 52(4), 573-600. Also, are all of these lock-in types and mechanisms relevant in energy systems?	Editorial	Haris Doukas	School of Electrical and Computer Engineering, National Technical University of Athens	Greece
44633	111	9	111	35	Two additional aspects on inertia might be includeded here: status quo orientation of senior public officials (see https://onlinelibrary.wiley.com/doi/abs/10.1002/wcc.305) and path dependencies created by 'instrument constituencies' (see https://onlinelibrary.wiley.com/doi/abs/10.1111/gove.12179)	Accepted. Added to text.	Oliver Geden	German Institute for International and Security Affairs	Germany
5701	111	9	112	35	This or another relevant section should refer to the ongoing trend toward fossil fuel divestment by pensions and other funds, and the potential role for changing investment flows.	Taken into account. Section 6.3 covers some of these investment effects into fossil fuels.	Seth Seth Dunn	General Electric	United States of America
17719	111	9	115	25	I think this section partly misses the core point of the Geels et al transition framework, which is flagged in Chapter 1. A substantial part of the inertia comes from the 'meso level' of interacting market structures, existing regulatory regimes, and multiple forms of vested interests and mindsets. THis creates not only obvious poitical but more subtle network related rigidities which can only be overcome by quite strong policy. The role of SOEs (eg. in Asia), which are the main funders of coal (briefly noted and referenced in chapter 1) could also be mentioned. At the more general level, also see Aghion, P., C. Hepburn, A. Teytelboym, and D. Zhengelis (2019). Path dependence, innovation and the economics of climate change. Handbook on Green Growth, 67–83. https://doi.org/10.4337/9781788110686.00011	Noted. This section focusses on energy system lock-in. Chapter 1 covers broader impacts into the general mitigation framework.	Michael Grubb	UCL - Institute of Sustainable Resources	United Kingdom (of Great Britain and Northern Ireland)
26081	111	15	112	6	Embedding or path dependence can be especially strong in heavy industry, where older, higher emissions, very long life facilities are often the foundation for a much higher value added and lower emissions intensity local manufacturing system.	Noted. That is the intent of Figure 6.46.	CHRISTOPHER BATAILLE	IDDRI.ORG/SIMON FRASER UNVIERSITY	Canada

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
35605	111				lock-in is poorly defined and path dependence is not defined at all. Good definitions are available https://doi.org/10.1038/s41560-019-0383-5	Accepted. Definitions to path dependence and carbon lock-in have been added.	Robert Gross	Imperial College and UKERC	United Kingdom (of Great Britain and Northern Ireland)
10919	112	7	112	35	This paragraph contains a number of crude and outdated generalisations (e.g. around the attractiveness level of demand-side solutions), provides limited detailed insight, and contains virtually no references to existing research. The paragraph needs significant expansion to improve accuracy, reflect more recent trends in public and other groups' engagement with energy issues, and to provide more detailed insights on techniques for promoting the levels of engagement suggested without engaging in policy prescription. Greater cross-referencing with Chapter 5 is also needed to improve continuity and to provide some of the necessary detail.	Accepted. Several new references have been added to include these effects.	Ian Bailey	University of Plymouth	United Kingdom (of Great Britain and Northern Ireland)
15723	112	7	112	35	In this paragraph you may want to consider discussion of policy for directed technological change/innovation, especially for key needed technologies. Kavlak et al 2018 (already referenced) provides a historical assessment for solar PV, Grubb et al 2014 considers it more generally, and Bataille (2019) considers it in the context of long lived, risk averse heavy industry using the UK's policy mechanisms develop and de-risk offshore wind as a example. Additional sources: Grubb, M. (2014). Planetary economics: energy, climate change and the three domains of sustainable development. Routledge; Bataille, C. 2019. Physical and policy pathways to net-zero emissions industry. WIREs Climate Change. 2020;11:e633. https://doi.org/10.1002/wcc.633	Taken into account. This has been discussed in 6.7.5.	CHRISTOPHER BATAILLE	IDDRI.ORG/SIMON FRASER UNVIERSITY	Canada
4499	112	28	112	31	Suggest to include the following after the sentence ending line 31: The energy transition arises from interactions between new technologies, business models, financing mechanisms, policy instruments, a skilled workforce and societal change. Innovations in technology, policy, regulatory and market frameworks, financing instruments, operational and planning practices and business models can re-enforce each other towards energy systems increasingly based on renewable energy, energy efficiency, communication and information technologies and smart and flexible infrastructure.	Noted. We have chosen not to add this because of page constraints but we appreciate this point.	Leonardo Barreto	Austrian Energy Agency	Austria
5659	112	36	115	25	This section on physical lock-in should also discuss the significant lock-in risks due to investments in fossil energy-consuming infrastructure in the industrial sector. In other words, lock-in is not just an issue confined to energy supply systems. For example, the following reference showed that the GHG emissions associated with new and planned industrial facilities in the U.S. Gulf Coast region (e.g., petrochemical plants) stimulated by the shale boom could grow to as much as 7% of U.S. GHG emissions by 2030. Waxman, A.R., Khomaini, A., Leibowicz, B.D., Olmstead, S.M., 2020. Emissions in the stream: Estimating the greenhouse gas impacts of an oil and gas boom. Environmental Research Letters 15, 014004.	Accepted. This has been added in the adjoining box on stranded assets.	Benjamin Leibowicz	The University of Texas at Austin	United States of America
11427	112	36	115	25	Section Physical Energy System Lock-In: cross-check and cross-reference this section with section 2.8.2 Committed emissions from energy infrastructures in Chapter 2	Accepted. Text modified.	Thomas Wiedmann	UNSW	Australia
20449	112	36	115	25	Ram et al. (http://energywatchgroup.org/wp-content/uploads/EWG_LUT_100RE_All_Sectors_Global_Report_2019.pdf) show that the carbon lock-in is not that severe, since a fossil-free energy system can be achieved by 2050 as a least cost case - such literature findings need to be reflected in this section.	Accepted. We have noted such literature in the text.	Christian Breyer	LUT University	Finland
11509	112	36	117	28	With regard to carbon-lock-in effect, which means a perpetual inertia caused by a fossil fuel based energy system, there are many researches to overcome this problem. However, in case that existing electricity, oil and gas companies have dominat power in a country and region, lobby activity by them can significantly distort the policy toward carbon lock-out.(carbon lobby). In th US Lobbying Disclosure Act(1995) and Open Government Act(2007) were established and fonctionned to some extent to avoid distortions by enhance transparency. In EU, the European Transparency Initiative was published in 2006 and the first European Commission lobby register was set up in 2008. There are still many loopholes in these systems. However, in order to make carbon lock-out effective, it is indispensable to enhance transparency regarding carbon lobby. This point should be argued as one of implications.	Noted. The impacts of lobbying induced policy bias have now been mentioned. However this is a general concept and not limited to carbon lock-in effect alone.	Muneki Adachi	University	Japan
2163	112	36			This section is very interesting and useful	Noted.	Amy Townsend-Small	University of Cincinnati	United States of America
37875	112	36			In addition to the bottom-up literature on carbon lock-in, please also consider quantifications available from the scneario literature. In our paper Luderer et al. NCC (dx.doi.org/10.1038/s41558-018-0198-6) we quantified the impacts of delaying action for 10 more years in the context of the 1.5 and 2°C targets, and found that the medium- to long-term emissions commitment increases by 200-300 GtCO2. The sectoral composition of these lock-ins discussed in the seems highly relevant here.	Accepted. Added into text.	Gunnar Luderer	Potsdam Institute for Climate Impact Research	Germany

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
6055	113	7	113	8	Can please provide data (list of plants) for this estimates 'Further, coal-fired power plants that are currently under construction or planned for the future are associated with an additional ~300 Gt-CO2.'? Need to know if the basis CO2 estimation method whether taken into consideration newer coal technologies which emit lower CO2 per MW due to higher efficiency etc	Taken into account. Further details have been provided in the box on stranded assets giving details.	SAIK PENG, CASEY NGO	R-SYNC TECHNICAL RESOURCES SDN. BHD.	Malaysia
27881	113	13	113	13	Avoid the use of 'must'. It sounds policy prescriptive. Suggest rewording or phrasing the sentence conditionally.	Accepted. We have modified the text.	Jenkins Rhosanna	University of East Anglia	United Kingdom (of Great Britain and Northern Ireland)
11365	113	16	113	17	'The world's existing…. Shown in Fig. 6.40'- The sentence may be modified to make it more understandable	Accepted. Text modified.	PINAKI SARKAR	CSIR-CENTRAL INSTITUTE OF MINING AND FUEL RESEARCH	India
17721	113				Including Fig 6.39. In my view the most appropriate term here could be 'carbon assets at risk'?	Accepted. Text modified.	Michael Grubb	UCL - Institute of Sustainable Resources	United Kingdom (of Great Britain and Northern Ireland)
17043	114	2	114	13	When it comes to the premature retirement of fossil fuel reliant infrastructure, whether the additon of CCS is considered or not should be discussed, as the addition of CCS technology could postpone the retirement of fossil fuel reliant system, and thus reduce the capital loss.	Taken into account. The impact of CCS on premature retirement has been covered in the stranded assets box and section 6.7.4.	Qing YANG	Harvard University	China
34435	114	18	114	18	Add: or appropriately designed for fuel switching, e.g. using CCU technologies.	Taken into account. The impact of CCS on premature retirement has been covered in the stranded assets box and section 6.7.4.	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
18761	114	19	114	19	NETs are referred to earlier in the chapter as CDR - would it be better to choose one to stick to throughout?	Accepted. We have modified the text to be consistent with the CDR terminology.	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
18031	114	23	114	23	also can cite Budinis (2017) Energy Procedia V114 p7504 and IEAGHG report 2016-05 as further evidence	Accepted. Reference added.	Tim Dixon	IEAGHG	United Kingdom (of Great Britain and Northern Ireland)
31859	114	25	114	25	The sentence "Fig 6.41 shows the role of CCS …" should be qualified by something on the lines of "based on assumptions made about CCS costs, feasibility etc. in [citation]". Otherwise this seems too absolute a claim to make, when there are so many uncertainties about CCS.	Taken into account. The figure has now been modified. The prior figure was a mockup figure.	Ashok Sreenivas	Prayas (Energy Group)	India
18763	114	35	114	36	Apart from the power sector, there is considerable lock-in in the urban sector through buildings and transport.' - there would seem to be significant time differences between the stock turnover of buildings and transport sector, particularly passenger vehicles. Could this be reflected in an addition to the sentence e.g. '..., although the decades for stock turnover for buildings is substantially longer than that for passenger vehicles.'	Accepted. We have included this references in the adjoining box on stranded assets.	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
27883	115	8	115	8	Avoid the use of 'must'. It sounds policy prescriptive. Suggest rewording or phrasing the sentence conditionally.	Accepted. Text modified.	Jenkins Rhosanna	University of East Anglia	United Kingdom (of Great Britain and Northern Ireland)
20451	115	26	117	28	this section does not refelect the full body of literature and requires revision. Ram et al. (http://energywatchgroup.org/wp-content/uploads/EWG_LUT_100RE_All_Sectors_Global_Report_2019.pdf) show that fossil fuels can be phased out for the energy system, since renewable-based options are available for identical specific energy system cost as the present energy system. This literature finding is not reflected in the entire section.	Accepted. We have included the citation to Ram et al, 2018; 2020 in the text and indicate the renewable based options for transitions.	Christian Breyer	LUT University	Finland
11367	115	29	115	42	line 29-30 &41-42: for a 2o scenario unabated fossil fuel….. below renewables' . repetition of same sentence. Correction may be considered	Accepted.Text modified.	PINAKI SARKAR	CSIR-CENTRAL INSTITUTE OF MINING AND FUEL RESEARCH	India
44189	115	30	115	31	The correct reference is (instead of Gambhir et al., 2015): Gambhir et al (2017) Assessing the Feasibility of Global Long-Term Mitigation Scenarios, Energies, 10(1), 89, https://doi.org/10.3390/en10010089	Accepted. Change has been made.	Ajay Gambhir	Imperial College London	United Kingdom (of Great Britain and Northern Ireland)
43047	115	37	115	37	will this box be included in the chapter? Would be beneficial to see some detailed case examples of how coal phase out through dedicated policies is happening in practice	Accepted. Yes the box is added in section 6.3.	Parth Bhatia	Centre for Policy Research, New Delhi	India
4501	115	38	115	40	and earthquake risks (e.g. in the Netherlands)	Rejected. We have not been able to estabilish this based on our assessment of peer reviewed literature.	Leonardo Barreto	Austrian Energy Agency	Austria
22913	115	44	115	44	The word "heals" in the sentence of "Coal seems to have dug in its heals against climate change" seems to be "heels", please check again to make sure.	Accepted. Text modified.	Xiusheng Zhao	Tsinghua University	China
2165	115	44			should be "heels"	Accepted. Text modified.	Amy Townsend-Small	University of Cincinnati	United States of America
9619	115	44			The sentence "Coal seems to have dug in its heals…" (even ignoring the typo in heels" seems oddly political and ascribes actions/motives to an inanimate, distributed object (coal).	Accepted. Text modified.	David Sholl	Georgia Institute of Technology	United States of America

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
39689	116	3	116	4	The total coal use in the no-pol scenarios varies quite remarkably and must be considered very high in some of the models. If scenarios with this much coal are to remain in AR6, this needs to be motivated somehow and limitations to increased coal use discussed.	Taken into account. This figure is illustrative and will be modified based on AR6 scenarios.	Simon Davidsson Kurland	Chalmers University of Technology	Sweden
27977	116	8	116	8	IPCC states, "The first mechanism is to increase levels of CCS deployment in the upcoming decade." The most recent review on the ability of CCS to sequester carbon finds that CCS, as currently implemented, increases CO2, so CCS deployment will only destroy the planet. Please remove all reference in this document to using CCS or other CDR methods of reducing carbon: Sekera, J., and A. Lichtenberger, The carbon capture conundrum: Public need versus private gain, A public policy perspective on carbon dioxide capture, 2020, https://drive.google.com/file/d/1K-BIULOUtfSs5LVCS9ONaDzq7jeFmO-b/view conclude (1) many scientific studies pass carbon removal methods off as "climate mitigation" when in reality the methods in play today increase CO2 and (2) laws subsidizing carbon capture and direct air capture increase CO2. 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 similarly found that CCS/U and DACCS/U are both opportunity costs resulting in hardly any CO2 reduction, even before considering the disposition of CO2, and air pollution and mining increases.	Rejected. While a few papers indicate these results, the confidence level is low in this finding based on our conclusions on overall assessment of the literature.	Mark Jacobson	Stanford University	United States of America
10921	116	8	116	10	Do estimates of likely carbon prices needed exist in the literature?	Taken into account. Carbon prices discussion may be found in Section 6.7.5.	Ian Bailey	University of Plymouth	United Kingdom (of Great Britain and Northern Ireland)
34699	116	8	116	11	The role of CCS in the renewable transition is the value added provided (considering EROI) by the combination of renwables and CCSs compared with the CCS for the fossil fuel plants (Sgouridis, S., Carbajales-Dale, M., Csala, D. et al. Comparative net energy analysis of renewable electricity and carbon capture and storage. Nat Energy 4, 456–465 (2019). https://doi.org/10.1038/s41560-019-0365-7)	Taken into account. The impact on EROI has been covered in Section 6.4.2.7.	Jordi Solé-Ollé	Spanish National Research Council (CSIC)	Spain
34437	116	8	116	23	In this section, a discussion on the role of CCU as major contributor to enable a fast energy transition is lacking. The potential applications of CCU are diverse, ranging from using CO2 in greenhouses and farming to conversion of CO2 into fuels, chemicals, polymers and building materials. 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. There are also many new CO2-utilization technologies at various stages of development and commercialization. These technologies have the potential to provide opportunities for emission savings for power and other industrial sectors by substituting fossil-fuel raw materials, increasing efficiency and using renewable energy, and generating revenues through producing marketable products (e.g. Hepburn et al., 2019, Zhu, 2019). When the deployment of CCS can be compromised by its costs, CCU can offset some of the cost of CCS by providing additional revenue streams that create a more compelling business case. Also, CCU can be applied in closed-loop concepts (e.g. capturing CO2, producing CH4 through hydrogenation, using CH4 for energy purposes, capturing the emitted CO2 and repeating the cycle) or in permanent CO2 sequestration in building materials (e.g. through mineralization) thereby reducing the amounts that CCS needs to handle (Bruhn et al., 2016, Daggash et al., 2018, Koytsoumpa et al., 2018). (Daggash et al., 2018, Sustainable Energy Fuels, 2, 1153-1169./Koytsoumpa et al., 2018, The Journal of Supercritical Fluids, 132,3–16./• Hepburn et al., 2019: The technological and economic prospects for CO2 utilization and removal, 575, 87-97./Bruhn et al., 2016, Environmental Science & Policy, 60, 38–43./Zhu, 2019, Clean Energy, Vol. 3, No. 2, 85–100.)	Taken into account. The costs and potential of CCUS has been provided in section 6.4.2.5	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
2167	116	8			Upcoming decade, as in between 2020 and 2030? Previously in this chapter it said that CCS has only been deployed at the demonstration scale. Perhaps you need to add that this will take a major effort to deploy within this time scale.	Accepted. Text modified.	Amy Townsend-Small	University of Cincinnati	United States of America
18765	116	10	116	13	as arising from differences not just in GHG emissions but also end-use flexibility, air pollution and other externalities' - consider - 'as arising from differences not just in GHG emissions but also in the speed of fuel switching when using already built powerstations and infrastructure, and end-use flexibility, air pollution and other externalities (Wilson and Staffell, 2018)'	Noted.	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
29451	116	15	116	16	The sentence "degree to which CCS may mature technologically" is incorrect. CCS and all components in the technical chain of CCS are mature and commercially operating (TLR 8+) for over four decades. Reference: Global CCS Institute, 2019: Global Status Report 2019. https://www.globalccsinstitute.com/.	Taken into account. TRL levels of CCUS have been covered in 6.4.2.5.	Eve Tamme	Global Carbon Capture and Storage Institute	Belgium

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
29453	116	16	116	17	The sentence "reliable sequestration of CO2" is incorrect. CO2 has been stored both through dedicated geological storage and EOR for over for over four decades. Individual CO2 storage (EOR) projects are operating at scales of over 5MtCO2 per annum. The storing of CO2 very reliable. Reference: Global CCS Institute, 2019: Global Status Report 2019. https://www.globalccsinstitute.com/.	Accepted. Text modified.	Eve Tamme	Global Carbon Capture and Storage Institute	Belgium
18033	116	20	116	20	Although this can be countered with higher capture rates, see Feron (2019) Int Journal Greenhouse Gas Control V87 p188-202 and IEAGHG report 2019-02	Noted. This has not been included due to page constraints.	Tim Dixon	IEAGHG	United Kingdom (of Great Britain and Northern Ireland)
18035	116	20	116	20	Budinis has typo	Editorial	Tim Dixon	IEAGHG	United Kingdom (of Great Britain and Northern Ireland)
26229	116	20			Budinis (not Budnis)	Editorial	Sara Budinis	International Energy Agency	France
25091	116	31	116	34	Delete "Comparing to coal, … for a transition away from oil." as it depends on prices	Accepted. Text modified.	Eleni Kaditi	Organization of the Petroleum Exporting Countries (OPEC)	Austria
1535	117	0	117	0	#REF!	Editorial	Paul Vethman	PBL Netherlands Environmental Assessment Agency	Netherlands
1537	117	0	117	0	Besides policies from practice, there are legal developments that pave the way for policies that can realise the energy transition. Of course the Paris agreement is the most well known example worldwide, but other jurisdiction examples exists where governments create legal frameworks such as 'climate laws (acts)'. These capture ambitions related to climate change goals and roadmaps. A unique example is the Dutch government, that has been forced by legal court to protect its citizens by reducing emissions (referred to as the 'climate case'). News item: https://www.urgenda.nl/en/themas/climate-case/	Noted. We have based our assessment strongly on peer-reviewed literature.	Paul Vethman	PBL Netherlands Environmental Assessment Agency	Netherlands
11115	117	3	117	6	natural gas usage in the demand side (e.g. district heating, cooking, hot water supply, or even as co-generation system) will cause carbon lock in. Need to add sentences concerning importance of policy measures to refrain from natural gas usage to avoid unprecedented growth of natural gas comsumption and abate GHG emissions.	Taken into account. Lock-in effects are included in 6.7.3.	Midori Sasaki	industrial organization	Japan
5661	117	7	117	13	The reference included in my Comment #17 above is also highly relevant here. It shows that the GHG emissions associated with midstream and downstream facilities in the oil and gas value chain could actually be much larger than the emissions associated with methane leakage in the upstream segment. While methane emissions from oil and gas production have received a lot of attention in the literature, it appears that they are only a fraction of the overall GHG emissions impact of the industry.	Taken into account. Fugitive methane leakage has been covered in 6.4.2.7.	Benjamin Leibowicz	The University of Texas at Austin	United States of America
11121	117	9	117	9	the text says "As discussed in Section 6.4 ..." but the referenced subclause should be 6.3.4.	Editorial	Midori Sasaki	industrial organization	Japan
18767	117	10	117	13	Thus, while some life-cycle studies conclude definitively for coal to be better than gas in GHG implications (Mallapragada et al. 2019; Wilson and Staffell 2018), others define leakage as critical parameter (Qin et al. 2017; Tanaka et al. 2019; Grubert and Brandt 2019).' If the wording of the first part of the sentence is suggesting that the unabated combustion of coal had less GHG impacts than natural gas - then the Wilson and Staffell 2018 should not be used as a reference - as the article made the opposite point - that switching from coal to natural gas for electrical generation had reduced overall emissions. For the second part - the Sustainable Gas Institute's White Paper 1: Methane and CO2 emissions from the natural gas supply chain (Balcolmbe et al. 2015) https://www.sustainablegasinstitute.org/methane-and-co2-emissions-gas-supply-chain/ is an excellent reference that considers fugutive supply chain emissions.	Accepted. Text modified.	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
26319	117	12	117	13	I think that the story is not just about CH4 leakage and there are more factors that can be responsible for the outcome. Tanaka et al. (2019, 10.1038/s41558-019-0457-1) stress the fact that the choice of emission metrics such as GWPs and GTPs can dictate the outcome. Note that the study further looked into the sensitivities with respect to underlying emission data (e.g. plant efficiencies), the locations of emissions and imapcts, and the role of climate forcers other than CO2 and CH4.	Noted. We appreciate the suggestion but a discussion of GTP versus GWP is beyond the scope of this chapter and is covered elsewhere.	Tanaka Katsumasa	Laboratoire des Sciences du Climat et de l'Environnement (LSCE), CEA, FRANCE; National Institute for Environmental Studies (NIES), JAPAN	France
25093	117	14	117	15	Delete ""sustainable transition" pathways have … numerous other co-benefits." as this coclusion does not apply for all countries/regions	Accepted. Text modified.	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
36527	117	14	117	16	Do these number include both operation and production? It depends on types of fuels and renewable, but in general it is understood that PV and wind power require less number of workforce for operation and maintenance. These number is interesting and it is better to explain more how to get these numbers. It is suggested to refer the analysis of “EU coal regions; opportunities and challenges ahead” too. This analyze the impact of coal phase out in EU on the local employment and, in the local level, new investment for renewable in the region will not absorbed unemployment at coal sector to be emerged by the phase out coal.	Noted.. Our assessment is based on existing literature.	Takashi Hongo	Mitsui & Co. Global Strategic Studies Institute	Japan
46731	117	15	117	15	Please add Mikael Karlsson, Eva Alfredsson & Nils Westling (2020) Climate policy co-benefits: a review, Climate Policy, DOI: 10.1080/14693062.2020.1724070.	Accepted. Text modified.	Mikael Karlsson	KTH Royal Institute of Technology	Sweden
17045	117	15	117	15	"fossil fuels generate are estimated to generate 2.65 jobs" seems to have duplicated the "generate"	Accepted. Text modified.	Qing YANG	Harvard University	China
17543	117	15	117	15	extra word "generate"	Accepted. Text modified.	Katherine Romanak	The University of Texas at Austin	United States of America
18769	117	15	117	15	For instance, fossil fuels generate are estimated to generate' repeat of generate - should be 'For instance, fossil fuels are estimated to generate …'	Accepted. Text modified.	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
9621	117	25			Not immediately clear to me what "duck curve" means	Taken into account. This has been discussed in 6.4.	David Sholl	Georgia Institute of Technology	United States of America
6469	117	29	118	44	Maybe I missed it but is there anything on supply-side policies / deposit markets? This should be a good starting point to look into this matter: Asheim, G. B., Fæhn, T., Nyborg, K., Greaker, M., Hagem, C., Harstad, B., ... & Rosendahl, K. E. (2019). The case for a supply-side climate treaty. Science, 365(6451), 325-327. DOI: 10.1126/science.aax5011	Accepted. We added a paragraph on leakage and also refer to supply-side policies.	Paul Neetzow	Humboldt-Universität zu Berlin	Germany
17725	117	29	118	44	Samuel Fankhauser (2013) A practitioner's guide to a low-carbon economy: lessons from the UK, Climate Policy, 13:3, 345-362, DOI: 10.1080/14693062.2013.749124	Noted. Comment is jointly discussed with Comment ID #17727.	Michael Grubb	UCL - Institute of Sustainable Resources	United Kingdom (of Great Britain and Northern Ireland)
17727	117	29	118	44	This section probably could be strengthened but it is twoards the end of a very long chapter. Would be good to coorinate particularly with Chapter 13. If wanting to draw additionally on the UK transition, a good if relatively early ref could be Samuel Fankhauser (2013) A practitioner's guide to a low-carbon economy: lessons from the UK, Climate Policy, 13:3, 345-362, DOI: 10.1080/14693062.2013.749124	Accepted. We added the reference to UK as another real world example.	Michael Grubb	UCL - Institute of Sustainable Resources	United Kingdom (of Great Britain and Northern Ireland)
43049	117	29	118	44	This section deserves credit for pointing out the complexity of sequencing policies to achieve a low carbon transformation, and for pointing out the "mix" nature of real world policy. The section also rightly critiques the absence of analyses of real world policy mixes (line 14, pg 118). However, the section focuses a lot on energy transition scenarios and doesn't say enough about empirical experiences with designing or implementing a mix of policies which could drive a nationa transformation. The example of the German Energiewende is a good one, however it is touched upon briefly. This section would benefit from deeper engagement with real world policy packages or instrument mixes being deployed at national scales and the challenges and insights from empirical experiences. In case there isn't much literature looking at such questions, a case study can be fleshed out to give policy makers insights regarding deliberately designing or altering policy mixes and their interactions with the local governance context.	Taken into account. Besides the discussion of ex-ante scenario analyses of policies, we included insights gained from ex-post analyses of actual implemented policy mixes.	Parth Bhatia	Centre for Policy Research, New Delhi	India
25881	117	29	121	38	There are overlaps between this section and Chapter 13, especially on the part on behaviour; however despite the thematic overlap I am not sure the two chapters reflect the same literature on these issue, so it would be good to clarify the differences, and why some perspective are more relevant in one chapter than in the other (if applicable).	Taken into account. We made sure that we cited the relevant literature, i.e. the one focusing on the energy sector, from Chapter 13.	Béatrice Cointe	Centre de Sociologie de l'Innovation i3, CNRS UMR9217	France
16291	117	29			In Section 6.7.5 Policy and Governance, consider adding a description of global military GHG emissions, and the potential for militaries and other governmental agencies to lead the transition to carbon neutrality.	Taken into account, we have referred to the discussions of invidual policies (in this case, public procurement) in Chapter 13	Daniel Helman	College of Micronesia-FSM	Micronesia, Federated States of
4503	117	30	117	31	Solid governance is fundamental for the implementation of low-carbon energy systems and must integrate interlinkages between policy areas (e.g. energy efficiency, renewable energy and buildings), breaking silos, promiting sector integration and promoting multi-level energy and climate dialogue and regional cooperation to ensure policy implementation	Taken into account. Added a sentence after the first sentence of the subsection.	Leonardo Barreto	Austrian Energy Agency	Austria

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
26083	117	34	117	36	As a complement to the IAM family of SSPs (Krielger et al 2014) and the following sentence (Kube et al 2018) on the weaknesses of carbon pricing as the sole policy instrument, and building on Stiglitz and Stern (2017)'s "High Commission on Carbon Pricing", Bataille, Guivarch, Hallegate, Rogelj and Waisman 2018 (already referenced in the chapter) explores carbon pricing and complementary policies in diverging real word national contexts. With country-specific development objectives and constraints, multiple market failures and limited international transfers, carbon prices do not need to be uniform across countries, but must be part of broader policy packages of complementary policies.	Taken into account. Added reference to a later part of the text.	CHRISTOPHER BATAILLE	IDDRI.ORG/SIMON FRASER UNVIERSITY	Canada
15531	117	35	117	36	The statement that academic research focuses mainly on market-based approaches seems unnecessarily constraining. There are many other approaches that feature prominently in the literature. See e.g. Green, F. & Denniss, R. Cutting with both arms of the scissors: the economic and political case for restrictive supply-side climate policies. Climatic Change 150, 73–87 (2018) & Piggot, G., Erickson, P., van Asselt, H. & Lazarus, M. Swimming upstream: Addressing fossil fuel supply under the UNFCCC. Climate Policy 18, 1189–1202 (2018) & Erickson, P., Lazarus, M. & Piggot, G. Limiting fossil fuel production as the next big step in climate policy. Nature Climate Change 8, 1037–1043 (2018).	Taken into account. We revised the sentence and limit the focus on environmental economics (as this is the focus of the review paper by Kube et al on research trends). We added another sentence to acknowledge the larger discussion on various policy approaches in academic research overall.	Peter Erickson	Stockholm Environment Institute	United States of America
44325	117	35	117	36	For energy efficiency in buildings regulatory policies are widely implemented in the form of appliances standards and building codes. In the EU and other jurisdiction building codes mamdates NZEBs for new building. Market based instrument tends to be less effective in the building sector.	Taken into account. (Environmental) effectiveness is only one criteria and the sentence stressed the economic effectiveness ("least cost"). However, we stressed not that policy packages are evaluated along different criteria (explicitly environmental and economic effectiveness as well as distributional effects and reference to Chapter 13).	BERTOLDI PAOLO	European Commission	Italy
44327	117	36	177	36	in addition, to mixes very ofter policy packahes are adopted with different type of instruments part of a coherent strategy.	Accepted. Specifically mentioned "policy mixes (or policy packages)".	BERTOLDI PAOLO	European Commission	Italy
25877	117	42			The phrase "Policy mixes have different causes" sounds strange, as it seems to suggest that policy mixes are exogenous entities. "Policy mixes are shaped by different factors, including..." might be a better phrasing.	Accepted. Sentence revised.	Béatrice Cointe	Centre de Sociologie de l'Innovation i3, CNRS UMR9217	France
24679	117	44	118	2	From a pure mathematical point of view, multiple goals increase the costs of transition. They cannot be optimal from an economic point of view. Compared to erality, it appears that the strong carbon values required to trigger transtion are not socailly acceptable ("yellow vest" effect in France for instance. The complementaty goals can limit the explicit value of carbon (carbon ETS price or tax), but they increase the global costs of transition. One cannot say that multiple goal reduce costs. But one can consider that, given the fact that the society is not able to accept large explicit carbon value, the multiple goals are more effective in reducing the emissions, even if at a higher cost. So, "Complementary technology policies reduce the APPARENT mitigation costs...." If the anticipation was correct, the transition would be done at the least cost. The complementary provisions increases the cost of transition compared to the optimal one.	Partly accepted / rejected. The first part of the efficiency of multiple goals ignores that there are actual multiple goals that are pursued. The discussion here does not focus on the optimal goals but on policy mixes to achieve those goals. The second part regarding the apparent mitigation costs is now explicitly addressed in the text.	Florent LE STRAT	ELECTRICTE DE FRANCE	France
4505	118	3	118	4	for example, interactions between energy efficiency and renewable energy policies, which require coordinated implementation, specifically in the buildings. Suggest tomake a link to chapter 9 (Buildings) here.	Rejected. Comment refers to goals and not to specific policy mixes which is the focus of this section	Leonardo Barreto	Austrian Energy Agency	Austria
25879	118	5			Why is the word "optimal" between inverted commas? It makes it ambiguous, as one does not know 1) what definition of optimal is refered to and 2) whether the phrase accepts this definition or dismisses it	Accepted. Text revised.	Béatrice Cointe	Centre de Sociologie de l'Innovation i3, CNRS UMR9217	France
17047	118	23	118	26	I suggest that the results or conclusions of this comparison should be presented.	Accepted. Added a sentence on the results.	Qing YANG	Harvard University	China
44329	118	28	118	33	The EU has adopted a Regulation fo the non ETS sector which described the policy measure for buildings and trasnport, in particular for buildings and products under the EPBD and Ecodeisgn mandatory energy effciency standards are implemented. A comphensive description of the EU energy efficiency policies forteh building sector are available at: A description is in: Chapter 2 - Policies, Recommendations and Standards (International Technical Standards, Main Laws and Regulations; EU Directives; Energy Labeling), Editor(s): Francesco Asdrubali, Umberto Desideri, Handbook of Energy Efficiency in Buildings, Butterworth-Heinemann, 2019, Pages 5-73, ISBN 9780128128176, https://doi.org/10.1016/B978-0-12-812817-6.00002-4. (http://www.sciencedirect.com/science/article/pii/B9780128128176000024)	Taken into account. "Non-ETS" is now explicitly mentioned; references to particular EU policy does not seem fitting here.	BERTOLDI PAOLO	European Commission	Italy

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
24681	118	40	118	40	The absence of difference in the LTS scenario before 2030 is clearly linked to the lack of anticipatono of 2050 target before 2031. Once again, if the 2050 was correctly anticipated, the pathways shouls be different.	Taken into account. We made the statement more precise by stressing that the result is an outcome of one particular study. Regarding the reasons for the absence of difference it is unclear what would have happened to the pathways with 2050 target (this would depend on assumptions on capital accumulation, innovation etc.)	Florent LE STRAT	ELECTRICTE DE FRANCE	France
20453	118	43	118	44	the statement is not correct since literature exists with diametal different findings - more references and literature has to be worked in to represent the state-of-the-art in this part. On a global-local level Ram et al. (http://energywatchgroup.org/wp-content/uploads/EWG_LUT_100RE_All_Sectors_Global_Report_2019.pdf ; also part of AR6 sceanrio database) show that total system cost per used energy unit can be even lower in a 100% renewable system with broad Power-to-X application. For the case of Chile this is shown in detail (https://journals.aau.dk/index.php/sepm/article/view/3385). More balanced wording is required, which in particularly includes the state of the art, as also presented by Hansen et al. (https://www.sciencedirect.com/science/article/pii/S0360544219304967)	Taken into account. We added some more sentences on 100% renewable scenarios.	Christian Breyer	LUT University	Finland
10003	119	2	119	5	Useful references: - 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. - 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.	Noted, this section focuses on individual behaviour change, institional factors are extensively discussed in Chapter 5.	Haris Doukas	School of Electrical and Computer Engineering, National Technical University of Athens	Greece
11445	119	5	119	9	The wording states that civil society needs to 'adopt' behaviours and 'accept' system changes. This sounds like system change should be something that is imposed on citizens, rather than co-designed and co-created with citizens. Research has shown that long-term systemic change is better achieved when members of society have input across all stages including the design, implementation and evaluation of initiatives, stragegies and policy decisions. Yet, these type of initiatives remain the exception. for a review of 249 sustainable energy initiatives in 27 European countries see Goggins, G., Fahy, F. and Jensen, C.L. (2019) Sustainable transitions in residential energy use: Characteristics and governance of urban-based initiatives across Europe. Journal of Cleaner Production, 237. https://doi.org/10.1016/j.jclepro.2019.117776	We made sure text is not policy prescriptive	Gary Goggins	National Univeristy of Ireland Galway	Ireland
11447	119	10	121	38	To meet climate targets requires systemic change. Systemic change can come about by targeting the social organization of society and restructuring systems of production and consumption, which is far more effective that targeting individual behaviour change and isolated behaviours (as mostly described in this section). Systemic change also requires integrated changes in social and technical systems (socio-technical change), as technological change by itself will not deliver the reductions in carbon emissions required. How the problem of unsustainable energy use is understood (i.e. the problem-framing) has a major impact on the type of solutions that are persued. In a review of over 1000 sustainable energy initiatives, Jensen et al (2019) found that over 75% of initiatives took a rather simplistic approach of targeting changes in technology or changes in individual behaviour, rather than targeting complex social systems that underpin energy use. To achieve the radical changes we need in our energy systems, we need to start to think about more systemic solutions. See Jensen, C.L., Goggins, G., Røpke, I. and Fahy, F. (2019) Achieving sustainability transitions in residential energy use across Europe: The importance of problem framings. Energy Policy, 133. https://doi.org/10.1016/j.enpol.2019.110927	Noted, systemic change is discussed in 6.6 and in other sections of 6.7 - behaviour change is part of systemic change	Gary Goggins	National Univeristy of Ireland Galway	Ireland
17723	119	14			I think in the unlinked reference this may be a misspealling of my name, in which case it probably refers to Grubb M.J., W.McDowell and P.Drummond (2017), On order and complexity in innovations systems: Conceptual frameworks for policy mixes in sustainability, transitions, Energy Research and Social Sciences, Vol.33:pp21-34. http://authors.elsevier.com/sd/article/S2214629617302827 [alternatively, with a bit more detail, chapter 12 in Grubb, Hourcade and Neuhoff (2014), Planetary Economics	Editorial	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
10005	119	32	119	44	Financial incentives like feed-in-tariffs should also be planned in consideration of other factors and levels of potential uptake, or may lead to negative consequences that could help formulate, in turn, a non-favourable environment, leading to the exact opposite result, e.g.: - Sorman, A. H., Pizarro-Irizar, C., García-Muros, X., González-Eguino, M., & Arto, I. (2019). On a rollercoaster of regulatory change–risks and uncertainties associated with renewable energy transitions. Narratives of Low-Carbon Transitions, 121. - 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. - Nikas, A., Gkonis, N., Forouli, A., Siskos, E., Arsenopoulos, A., Papapostolou, A., ... & Doukas, H. (2019). Greece: From near-term actions to long-term pathways–risks and uncertainties associated with the national energy efficiency framework. In Narratives of Low-Carbon Transitions (Open Access) (pp. 180-198). Routledge.	Accepted, this is discussed on p 119, line 39-44 f FOD	Haris Doukas	School of Electrical and Computer Engineering, National Technical University of Athens	Greece
43985	119				The question of overcoming societal inertia in time is a crucial one. Can the assessment provide an overview of the right mix between personal motivation and implementation of various policy options in terms of the effectiveness in overcoming the inertia, if such differentiation is possible.	Noted, the literatue does not allow for such an assessment is not possible, and the right mix will differ across behaviours, groups, and regions, depending on which factors inhibit or enable the behaviour of the relevant group. This is indicated in the first paragraphf of 6.7.6.1,p 119, line 11-18 of the FOD	Hans Poertner and Elvira Poloczanska	Alfred-Wegener-Institut	Germany
15791	120	10	120	11	The following article by the Climate Interactive staff "Combining role-play with interactive simulation to motivate informed climate action: Evidence from the World Climate simulation" J. N. Rooney-Varga, J. D. Sterman, et al, Published: August 30, 2018 https://doi.org/10.1371/journal.pone.0202877 states that: "We find statistically significant gains in three areas: (i) knowledge of climate change causes, dynamics and impacts; (ii) affective engagement including greater feelings of urgency and hope; and (iii) a desire to learn and do more about climate change. Contrary to the deficit model, gains in urgency were associated with gains in participants' desire to learn more and intent to act, while gains in climate knowledge were not. Gains were just as strong among American participants who oppose government regulation of free markets–a political ideology that has been linked to climate change denial in the US–suggesting the simulation's potential to reach across political divides. The results indicate that World Climate offers a climate change communication tool that enables people to learn and feel for themselves, which together have the potential to motivate action informed by science."	Noted, the gains mentioned do reflect changes in knowledge, sense of urgency, and desire to learn. Yet, the current section focuses on strategies to change behaviour, rather than knowledge, desires, and perceptions	EDUARDO PEDRO FRACASSI	ITBA Instituto Tecnologico de Buenos Aires	Argentina
44331	120	37	120	45	The effectiveness and the range of energy savings resulting from energy consumption feedback systems based on different media has been assessed on the following paper: Zangheri, P.; Serrenho, T.; Bertoldi, P. Energy Savings from Feedback Systems: A Meta-Studies' Review. Energies 2019, 12, 3788. (available at https://www.mdpi.com/1996-1073/12/19/3788/htm). It is recommended to cite it.	Accepted, reference added	BERTOLDI PAOLO	European Commission	Italy
17049	120	41	120	41	I can understand that "Simple information is more effective than detailed and technical data". But I propose that the other side of "simple information" should also be indicated; e.g., it sometimes may be misleading.	Accepted, simple is replaced by easy to comprehend	Qing YANG	Harvard University	China
44333	121	5	121	12	The effectiveness and the range of energy savings resulting from energy consumption feedback systems based on different media has been assessed on the following paper: Zangheri, P.; Serrenho, T.; Bertoldi, P. Energy Savings from Feedback Systems: A Meta-Studies' Review. Energies 2019, 12, 3788. (available at https://www.mdpi.com/1996-1073/12/19/3788/htm). It is recommended to cite it.	Accepted, reference added in the start	BERTOLDI PAOLO	European Commission	Italy
44335	121	20	121	20	for an analysis of the EU policies to promote a change in behaviour you could cite: Paolo Bertoldi, Chapter 4.3 - Overview of the European Union policies to promote more sustainable behaviours in energy end-users, Editor(s): Marta Lopes, Carlos Henggeler Antunes, Kathryn B. Janda, Energy and Behaviour, Academic Press, 2020, Pages 451-477, ISBN 9780128185674, https://doi.org/10.1016/B978-0-12-818567-4.00018-1. (http://www.sciencedirect.com/science/article/pii/B9780128185674000181)	Noted, the section is not aimed at discussing EU policy specifically	BERTOLDI PAOLO	European Commission	Italy
29281	121	20	121	33	I agree that community energy systems may also help to promote low carbon behaviours in many ways, but what about community-based energy systems and community ownership of utilities as means to change energy systems? This does not seem to be discussed in detail within the chapter. Even if the evidence is negative, it should be reported.	Noted, we could not find peer reviewed papers appropriate for such an assessment	Vanesa Castan Broto	University of Sheffield	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
15533	121	40	123	18	The section on "acceptability" of changes seems incomplete without a discussion about how misinformation by high-carbon actors has distorted societal notions of acceptability. There is a rich literature on this. See e.g. Farrell, J. Network structure and influence of the climate change counter-movement. Nature Climate Change 6, 370–374 (2015). Farrell, J., McConnell, K. & Brulle, R. Evidence-based strategies to combat scientific misinformation. Nature Climate Change 9, 191 (2019). Much additional work by Bob Brulle, Naomi Oreskes, many others.	Noted, the section focuses on factors influencing public acceptability, not on causes for uncenrtainty and doubt about climate change, or ways to combat misinformation. We agree that these are relevant and important topic, but they are beyond the mandate of this chapter of AR6	Peter Erickson	Stockholm Environment Institute	United States of America
15793	121	42	121	43	The online EN ROADS simulator and the Climate Action Simulation by Climate Interactive can help people visualize the energy transition pathways from a high carbon to a low carbon economy. It can help diferent "agents", that is a) individuals and househods, b) NGOs, social movements and c) the private sector understand which mitigation strategies are available and get a feeling of their impact on climate mitigation. Climate Interactive has made available the simulator at https://www.climateinteractive.org/tools/en-roads/ , with a list of key possible available mitigation strategies and climate actions that show in real time the projected temperatures created by aplying mitigation strategies the climate actions in a worldwide scale. Here is a link to their latest article, Rooney-Varga, J. N., Kapmeier, F., Sterman, J. D., Jones, A. P., Putko, M., Rath, K., The Climate Action Simulator, Simulation & Gaming, https://journals.sagepub.com/doi/full/10.1177/1046878119890643 A word of caution: this EN ROADS simulator is not an IAM, it is just an easy to use simulator for general public use in order to foster and to create more awareness on posible mitigation strategies that could lead to a 1.5 scenario. For example, it has been used by politicians, media, students, and public in general, as stated in Climate Interactive's page "A wide range of people have used En-ROADS, including members of the U.S. Congress, HSBC bank, the Hewlett Foundation, local community groups, the UN Secretary-General's Office, university professors around the world, leading science educator Bill Nye, and many others." at: https://www.climateinteractive.org/tools/en-roads/	Noted, public preferences for energy system transformatig that relied on similar tools are discussed in the last paragraph/sub section of Section 6.6.4	EDUARDO PEDRO FRACASSI	ITBA Instituto Tecnologico de Buenos Aires	Argentina
12905	122	1	122	5	Another important aspect of public acceptability of mitigation is also to educate on the dire need for mitigation. Tranparent rendering of the impacts of continuing with the business as usual scenarios in future, particularly if the populations have not experienced the full impact of the climate change, is vital, considering they have to bear the costs of mitigation. A strong rationale supported with scientific facts need to be provided to countering climate change sceptics who dismiss it as a part of the natural cycle of the earth, in a transparent manner is extremely important.	Noted - this is implied at p 122, line 8: public acceptability will be higher when people are aware of the positive consequences of change for self, others, or the environment. Yet, at the same time, education and information ofthe has limited effects, as indicated in section 6.7.6.1, p 120, line 11-14 of the FOD	ASHOK NEMA	Nuclear Power Corporation of India Limited	India
10923	122	2	122	5	Add references to support this startement. Bailey, I. and Darkal, H. (2018) (Not) talking about justice: justice self-recognition and the integration of energy and environmental-social justice into renewable energy siting, Local Environment, 23 (3): 335-351 could be used for this purpose.	Noted. The references are included in the following paragraphs, where each of the listed topics are explained	Ian Bailey	University of Plymouth	
18771	122	20	122	20	threat them with respect' - should be 'treat them with respect'	Editorial	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
10925	122	26	122	46	Nearly all the literature on justice and acceptability of climate policies cited relates to renewable energy siting decisions. However, the potential for justice issues to impact on other elements of climate policy, such as acceptance of carbon pricing to reduce energy emissions should also be recognised. One study examining this is: Bailey, I. (2017) Spatializing climate justice: Justice claim-making and carbon-pricing controversies in Australia, Annals of the American Association of Geographers, 107 (5): 1128-1143.	Noted - most literature on procedural fairness indeed focuses on citing decisions. Yet please not that not all reference refer to siting decisions, eg pricing policy (Schuitema et a 2011; Drews ad Van den Bergh 2016; Evensen et al. 2018). Moreover, we base our assessment mostly on empirical studies	Ian Bailey	University of Plymouth	United Kingdom (of Great Britain and Northern Ireland)
37865	123	19			There is an emerging and increasing strand of literature on system-level environmental impacts based on the integration of life-cycle assessment and energy transformation pathway methods. This is hihgly relevatn for this chapter as it provides a wide and comprehensive perspective on environmental impacts. References: Luderer, Gunnar, Michaja Pehl, Anders Arvesen, Thomas Gibon, Benjamin L. Bodirsky, Harmen Sytze de Boer, Oliver Fricko, u. a. „Environmental Co-Benefits and Adverse Side-Effects of Alternative Power Sector Decarbonization Strategies". Nature Communications 10, Nr. 1 (19. November 2019): 1–13. https://doi.org/10.1038/s41467-019-13067-8. Hertwich, Edgar G., Thomas Gibon, Evert A. Bouman, Anders Arvesen, Sangwon Suh, Garvin A. Heath, Joseph D. Bergesen, Andrea Ramirez, Mabel I. Vega, und Lei Shi. „Integrated Life-Cycle Assessment of Electricity-Supply Scenarios Confirms Global Environmental Benefit of Low-Carbon Technologies". Proceedings of the National Academy of Sciences 112, Nr. 20 (19. Mai 2015): 6277–82. https://doi.org/10.1073/pnas.1312753111. Gibon, Thomas, Edgar G. Hertwich, Anders Arvesen, Bhawna Singh, und Francesca Verones. „Health Benefits, Ecological Threats of Low-Carbon Electricity". Environmental Research Letters 12, Nr. 3 (2017): 034023. https://doi.org/10.1088/1748-9326/aa6047.	Accepted. These points have been included.	Gunnar Luderer	Potsdam Insttitute for Climate Impact Research	Germany

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
24683	123	24	123	24	About the costs of mitigation, they are never compared to the avoided costs of adaptation and damage. If they were integrated in the cost/benefice analysis, the mitigation policies would certainly appear less costly that they are presented !	Noted. The comparison of mitigation and adaptation costs is a useful point but is outside the scope of this chapter and is discussed in Chapter 17 (and other places)	Florent LE STRAT	ELECTRICTE DE FRANCE	France
18773	123	28	123	35	This paragraph seems a little different from others with the style (1) (2) (3) and mention of Chapter 17.	Accepted. The styling has been changed.	Grant Wilson	University of Birmingham	United Kingdom (of Great Britain and Northern Ireland)
31861	123	36	123	36	While the metric of economic costs in the aggregate is important, it is also important to unpack this a bit to see who pays the cost (and who gets the benefits). This aspect of possible contestation among different stakeholders / communities, some of whom lose and some of whom win, due to the transition does not appear to have been discussed. Of course, this applies to not just economic costs and benefits but costs and benefits in general.	Accepted. We have included some discussion on the distribution of costs pertaining to energy infrastructure.	Ashok Sreenivas	Prayas (Energy Group)	India
20637	123	40	123	41	A paper under review compares the techno-economic parameters and technology deployment strategies of a number of IAMs concerning different bioenergy technologies. It is similar to the Krey et al study cited but for a different set of technologies. It is an excelent study to further buttress the point made here. DAIOGLOU, V., ROSE, S., BAUER, N., KITOUS, A., MURATORI, M., SANO, F., FUJIMORI, S., GIDDEN, M., KATO, E., KERAMIDAS, K., KLEIN, D., LEBLANC, F., TSUTSUI, J., WISE, M. & VAN VUUREN, D. in review. Bioenergy technologies and climate change mitigation pathways: Results from the EMF33 study. Climatic Change.	Accepted. This has been added in section 6.4.2.7.	Vassilis Daioglou	Copernicus Institute of Sustainable Development	Netherlands
10927	123		126		Section 6.7.7 is relatively brief relative to its subject matter and would benefit from further expansion, in particular examining other sustainable development challenges relevant to energy transitions (water-energy is discussed currently) in order to provide governments with a fuller and sharper impression of the benefits of accelerating energy transitions for the achievement of human well-being focused SDGs. More case studies might be used to increase the impact of this section and it needs a robust concluding statement.	Accepted. Additional case studies (most importantly coal phaseout) are highlighted here.	Ian Bailey	University of Plymouth	United Kingdom (of Great Britain and Northern Ireland)
24685	124	3	124	3	From a global point of view, the carbon price is the marginal abatment cost, which should equal the marginal damage cost of the scenario in an optimal approach. Once again, this point is rarely prices because the adaptation/damage costs are not taken into account.	Noted. The comparison of mitigation and adaptation costs is a useful point but is outside the scope of this chapter and is discussed in Chapter 17 (and other places)	Florent LE STRAT	ELECTRICTE DE FRANCE	France
26085	124	3	124	6	The spread of carbon prices ($45-1050 & 245-14300/tco2) made me burst out laughing!:) "Carbon prices reflect the cost of mitigating at the margin and are found to be between 45–1050 USD2010 tCO2-eq in 2050 under a Higher-2°C pathway and range from 245–14300 USD2010 tCO2-5 eq for a Below-1.5°C pathway in 2050." To narrow this down a bit I suggest you follow with make reference to the carbon pricing (or equivalent regulations) suggestions of the Stiglitz and Stern High Commission on Carbon Prices here, i.e. the explicit carbon-price level that is consistent with achieving the Paris target, assuming a supportive policy environment, is at least $USD 40-80 per tonne by 2020 and $50-100 by 2030.	Noted. These carbon prices are broad because they reflect the prices across scenarios. Section 6.5 takes a more specific view of carbon pricing trends and approaches.	CHRISTOPHER BATAILLE	IDDRI.ORG/SIMON FRASER UNVIERSITY	Canada
19897	124	3	124	13	The paragraph starting from line 3 shows that required carbon prices are found to be between 45-1050 USD2010 tCO2-eq in 2050 under a Higher2-degree C pathway. On the other hand, the paragraph starting line 7 argus that total costs of shifting from a fossil-fuel based system towards a low carbon energy system well-below 2 degree C are moderate. They do not look consistent. Arguments downplaying economic costs for energy transformation are not convincing because they fail to explain slow progress of energy transformation as expected. Total cost may include operating cost, energy efficiency and infrastructure investment. Ribera et al.(2015) and OECD (2017) do not appear in the references.	Accepted. We have highligted the challenge of increasing energy investments)	Takahiko Tagami	Institute of Energy Economics, Japan	Japan
34701	124	7	124	8	Missing reference Ribera et al. 2015	Accepted. Text modified.	Jordi Solé-Ollé	Spanish National Research Council (CSIC)	Spain
45079	124	24	124	25	Relevant literature on SDG7, energy access and sustainable development may also be reviewed, such as "Assessing the impact of renewable energy on local development and the Sustainable Development Goals: Insights from a small Philippine island" and "Renewable electricity and sustainable development goals in the EU" as well as others from 2020.	Accepted. Text modified.	Siir Kilkis	The Scientific and Technological Research Council of Turkey	Turkey
41399	124	24	125	10	Why does this section on SDG7 only cover electricty and not even mention cooking energy?	Accepted. Reference to cooking energy has been made.	Cecilia Sundberg	Swedish University of Agricultural Sciences	Sweden
11369	124	31	124	32	'(Barron and Torero 2017; Agarwal and Toshniwal 2018) (Lam et al., 2016)' would be '(Barron and Torero 2017; Agarwal and Toshniwal 2018; Lam et al., 2016)'	Accepted. Text modified.	PINAKI SARKAR	CSIR-CENTRAL INSTITUTE OF MINING AND FUEL RESEARCH	India

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
17051	124	35	124	46	For one billion people who still lack access to electricity in developing countries, the policy suggestion to meanwhile meet the SDG of "access to clean and affordable energy" and climate mitigation target should be elabotared. On the one hand, the climate mitigation efforts may increase the difficulty for them to get energy. On the other hand, "the clean electrification" completed for them could serve as a reference for other regions with energy poverty to meet the climate goals. Thus I consider the efforts paid to the achieve both SDG and climate target for them are especially important.	Accepted. This point has been added in continuation with other chapters where it is pointed out that some SDGs are more relevant for developing countries while others are for developed countries.	Qing YANG	Harvard University	China
5967	124				Last paragraph, explanation on needs to reduce energy poverty. The claim is very accurate, but an emphasis on renewable energy might be over-simplified. Promotion of renewables is possible mostly for electricity, while direct use of electricity is more expensive than of fuels. In many developing countries, societies prefer to stay with no electricity to avoid bills. this leads to deforestation. Therefore, in some cases, an emphasis on low-carbon fossil fuels is less harmful to the climate change agenda than forcing people to the full electric option. In addition, the main issue in the developing world is the access to transport and development of industries. direct use of electricity in industry will make industries uncompetitive. For transport, large amounts of investments would be needed to expand electricity wires to have a wide network of charging stations. Majority of developing countries won't afford such investments. Hence, a reliance on fossil fuels will most probably persist. Therefore, efforts must be done in promotion more efficient fossil fuel technologies and low-carbon fossil fuels	Accepted. This point of competing energy investment versus climate action objectives has been made.	Belyi Andrei	University of Eastern Finland, Centre for Climate Change, Energy and Environmental Law	Estonia
17365	125	1	125	3	According to discussions held during COP25 and lack of international consensus in IPCC special report on the impacts of global warming of 1.5 °C above pre-industrial levels, the mentioned texts should appear to be reviewed.	Rejected. Our assessment here is based on peer-reviewed literature and relevant conclusions are accordingly drawn.	Zeyaeyan Sadegh	Islamic Republic of Iran Meteorological Organization (IRIMO)	Iran
27423	125	17	125	19	This article suggests that waste-to-energy supports SDG12 on sustainable consumption and production - "Waste-to-energy technologies can generate useful energy (electricity, heang/cooling) from disposables that are not suitable for recycling." But it ignores that SDG12.5 goal is "By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse". Again, waste-to-energy is a wide term that includes different technologies and it should be used with further specification. Moreover, waste-to-energy incineration has demonstrated that it competes with recycling (ref.needed), so that it actually undermines SDG 12. The references provided about this conflict needs to be included.	Accepted. Text modified to include this conflict.	Mariel Vilella Casaus	Zero Waste Europe	United Kingdom (of Great Britain and Northern Ireland)
19899	125	27	125	29	Figure 6.43 shows positive synergies between SDG 7 and non-energy SDGs. However, it should be noted that there is synergies and trade off within "affordable", "reliable" and "sustainable" within SDG7 and simultaneous achievement of these elements is not easy. This is the very reason why the share of renewable has not grown as quickly as expected and the role of coal cannot phase out so quickly.	Accepted. This point of competing energy investment versus climate action objectives has been made. Additionally, coal phaseout has been discussed in detail in section 3.	Takahiko Tagami	Institute of Energy Economics, Japan	Japan
34703	125	30	125	32	Ryan J. Klapperich, Daniel J. Stepan, Melanie D. Jensen, Charlie D. Gorecki, Edward N. teadman, John A. Harju, David V. Nakles, Andrea T. McNemar,The Nexus of Water and CCS: A Regional Carbon Sequestration Partnership Perspective,Energy Procedia,Volume 63,2014,Pages 7162-7172,ISSN 1876-6102, https://doi.org/10.1016/j.egypro.2014.11.752.	Accepted. Reference added.	Jordi Solé-Ollé	Spanish National Research Council (CSIC)	Spain
20639	125	30	126	31	A recent paper reviews the level of coverage of the Climate-Land-Energy-Water nexus in IAMs. It can offer important insights for this sections concerning (i) What IAMs can cover, (ii) What they cannot cover, and (iii) The level of detail with which they represent the relevant interactions, synergies, and tradeoffs. Johnson, N., Burek, P., Byers, E., Falchetta, G., Flörke, M., Fujimori, S., ... & Langan, S. (2019). Integrated solutions for the water-energy-land nexus: Are global models rising to the challenge?. Water, 11(11), 2223.	Accepted. This work has been cited on the inclusion of SDGs in IAMs.	Vassilis Daioglou	Copernicus Institute of Sustainable Development	Netherlands
18037	125	31	125	31	Disagree with "unprecedented". Water use with CCS does not have to increase. There are two reports that show that there are options to reduce or negate increased water use due to CCS. See IEAGHG report 2010/05 "Evaluation and Analysis of Water Usage of Power Plants with CO2 Capture" (March 2011) and Magneschi et al "The Impact of CO2 Capture on Water Requirements of Power Plants", GHGT-13, Energy Procedia 114 (2017) 6333-6347 , and IPCC (2018) SR1.5 Chap 5 p500	Accepted. The language has been modified.	Tim Dixon	IEAGHG	United Kingdom (of Great Britain and Northern Ireland)
44411	125	34	125	34	The term natural disaster does not have academic support, rather the term should be just disaster. If the triggering event needs to be identified then it is recommendable disaster triggered by a natural hazard. All disasters are social, as exposure and vulnerability are the ultimate causes of disaster. Quarantelli, E. L. (1985): «What Is Disaster? The Need for Clarification in Definition and Conceptualization in Research», en Disasters and Mental Health: Selected Contemporary Perspectives. U.S. Department of Health and Human Services, National Institute of Mental Health, pp. 41-73. Quarantelli, E. L. (1998): What is a Disaster? London, Routledge.	Accepted. Text modified.	Urbano Fra Paleo	University of Extremadura	Spain

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43987	125				options to reduce tradeoffs for life on land and life under water would be critical to alleviate the challenges for biodiversity. This as well as the tradeoffs for hunger should be highlighted and options discussed, in light of the findings by recent IPBES reports.	Accepted. Text has been modified to include this but the discussion here is limited as this point has been covered in other chapters.	Hans Poertner and Elvira Poloczanska	Alfred-Wegener-Institut	Germany
4137	172	11	172	13	The Walker and Baxter (2017) reference needs to be corrected.	Editorial. This should be corrected	Chad Walker	University of Exeter	United Kingdom (of Great Britain and Northern Ireland)
9255					Figure 6.34 Global energy sector CO2 emissions associated with different temperature goals (IPCC Scenario Database) (clear & representative)	Noted. Figure 6.34 will be updated.	Mounir Wahba Labib Risk	National Academy of Science, Egypt	Egypt
27857					p.103, l. 25 insert "It has been also proposed to develop a large contribution of nuclear power for future decarbonisation of the economy (Berger 2017a)(Berger2017b)" references: Berger, A. et al., 2017a: "Nuclear energy and bio energy carbon capture and storage, keys for obtaining 1.5°C mean surface temperature limit." International Journal of Global Energy Issues, 40(3/4), 240–254, doi:10.1504/ijgei.2017.086622. Berger, A. et al., 2017b: "How much can nuclear energy do about global warming?" International Journal of Global Energy Issues, 40(1/2), 43–78, doi:10.1504/ijgei.2017.080766. Would you accept to insert this type of scenario here? Renewable scenarios can veru well appear to be not feasible.	Noted. The contribution of nuclear energy is slightly touched in the "Energy transition strategies" section.	Frédéric Livet	CNRS-France	France
28811					Section 6.6.4.4 It is suggested that a portfolio of NETS all deployed at modest scales could be a more viable strategy than larger scale deployment. This is not explored to demonstrate why a modest scale deployment might be the most viable strategy. This should be unpacked in the SOD. How that proposal aligns with evidence regarding the need for large increases in CDR should be explored.	Noted. This section is reduced so ther is no room for detailed discussion, but the literature on the points raised is specified for reference.	Paul Rouse	Carnegie Climate Governance Initiative United Kingdom (of Great Britain and Northern Ireland)	United Kingdom (of Great Britain and Northern Ireland)
3081					This chapter should include the future trends of electric vehicles and heat pumps, i.e. the UK policy for 2040.	Rejected: These topics are more relevant to the transportation and building chapters.	Ahmed Zobaa	Brunel University London	United Kingdom (of Great Britain and Northern Ireland)
9395					no comment from my side	Noted	ANNA LAURA PISELLO	DEPARTMENT OF ENGINEERING - UNIVERSITY OF PERUGIA, ITALY	Italy
10929					Chapter 6 was lengthy and detailed but my general impression is that it may not be pitched as effectively as it might be. The opening focus on whole energy systems is promising because these connections between technology, policy, society and economics are crucial to understanding the barriers and opportunities for deep emissions cuts and how they might be addressed. However, for very long periods following this, the chapter appeared to become over-involved in technical descriptions of different energy sources and technologies and other elements of energy systems received relatively brief, and again often descriptive, treatment. Critical areas to be addressed more robustly in the SOD draft are the sections on societal preferences, policy options (including discussion of political issues affecting energy policy decisions), discusisons of djustice beyond the literature on acceptance of renewable energy by local communities, and linkages between energy transitions and other SDGs. The chapter is long enough already. Is the level of technical description in the first half of the chapter all needed? THe chapter seems to hide behind it to an extent.	Accepted/Rejected: As the only chapter assessing the technical characteristics of particular energy supply technologies as well as the characteristics of energy storage and integration technologies, a decent component of the chapter needs to be focused on these issues. This is unavoidable. In addition, details on poicy are addressed in other chapters. At the same time, we agree with the point that the system themes need to come out more clearly in the chapter and will be working to improve these themes in the SOD.	Ian Bailey	University of Plymouth	United Kingdom (of Great Britain and Northern Ireland)
11513					It is good to see that this chapter has a section on “The Costs and Benefits of Energy System Transitions in the Context of Sustainable Development”. However, there is lack of facts in monetary values of costs and benefits of various energy system transitions. Addition of these examples would be useful for investors, businesses, households or decision makers in motivations or transitions to low carbon economy or society. This chapter can provide some examples of costs and benefits (in monetary value) of energy system decarbonisation.	Same as 11519	Rawshan Ara Begum	Universiti kebangsaan Malaysia (UKM)	Malaysia
11525					Over the last five years a vast number of literature about 100% RES power scenarios or even 100% RES energy scenarios have been published. The chapter is lacking a critical review of these scenarios and mentiones only a selected few, which tend to be overnight scenarios without claer pathways.	Accepted. We have substantially increased the treatment of 100% renewable energy systems	Arnulf JÄGER-WALDAU	European Commission, JRC	Italy
12925					Some of the pre-AR5 (and even 2015) references may be no longer relevant given the rapid developments.	Accepted	Prashant Goswami	Institute of Frontier Science and Application	India
14383					Overall, as noted above, I think far too little is said about changes to the fossil energy system during the short to medium term, when it will still account for the majority of total global primary energy production. What of the growth of LNG production and trade for example. It gets no mention.	Taken into Account. We have enhanced our discussion of the fossil energy transition. This topic has its own subsection in 6.7	Michael Bradshaw	University of Warwick	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
15617					In general a very excellent work, a lot of information have been provided just that some areas will need re-ordering. Will make a presentation of my comments during the 3rd Lead Author Meeting "Mainstreaming Climate and Energy Policy" does not come clear in the document, even though 6.7.5 and 6.7.6 provide some elaboration.	Noted	Joseph Essandoh-Yeddu	Energy Commission	Ghana
20281					The waste sector contibution to energy is not clearly devoloped in this Chapter. This perhaps fills some of the gaps and wider associations ..... "Bio-wastes from food, and the environment including paper, wood, animal and human wastes can be spread (not always the best option) or composted to supplement soils or anaerobically digested to produced methane or thermally treated to produce a fuel or energy supply (Coolsweep 2017). In thermal treatments such as incineration there is an over economic reliance on high calorific plastic waste which creates a competitive dynamic with the plastics available for recycling (UNEP 2019). The largest proportion of plastic waste currently ends up dumped on land with over 4 to 12 million tonnes annually ending up in the global marine environment in 2010 (Jambeck et al. 2015). Plastic is mainly fossil fuel derived, so burning plastic contributes to CO2 emissions as it converts a long-term carbon locked source into CO2. Low quality mixed plastic waste imports from late 2017 were rejected by China and followed by other developing Asian countries. These wastes are being redirected to developing countries without enforceable import controls or resources to treat or dispose of these wastes (Sanderson 2018, Brookes et a., 2018) or as reported by the media being returned to countries of origin. There is on global scale significant environmental and ecosystem damage for failure of developed countries to adopt sustainable waste practices that co+I21uld have prevented this massive wastage that in the period 1950 to 2015 saw an estimated 4.9 trillion tonnes of plastic waste disposed in landfill or the natural environment. About 9% of all plastic wastes have been recycled with only 10% of this recycled more than once and 12% (0.8 trillion tonnes) incinerated over the same period (Geyer 2017). Waste to energy systems are often rejected on cost (UNEP 2019) in favour of low cost landfilling, but could be useful in the production of high value products such as activated carbon and carbon nanotubes from pyrolysis techniques and the production of fuel such as hydrogen from gasification technologies, as well as heat and power (Coolsweep 2017, UNEP 2019). Plastic related activities are relied by oil producers contributing up to 40 to 45% of GDP in the GCC countries (GPCA 2014) leaving WTE as a regional option which will maintain a proportion fossil fuel extraction (UNEP 2019). Fugitive fracking gas emissions have been proposed as a possible source for a rise of over 30% in US methane emissions in the decade before 2015 by linking it to a nine-fold increase in large scale fracking in the US over the period 2002 to 2014 (Turner et al. 2016). In the US, fracking development has been economically cushioned as a raw material source, significantly increasing production capacity for plastic and petrochemicals (Holden 2019).	Taken into Account / Rejected. We have updated the waste-to-energy discussion. However, do due space constraints, we do not have room for a discussion of how plastic waste is distributed around the world.	Paul Dumble	Paul's Environmt Lentd	United Kingdom (of Great Britain and Northern Ireland)
20281					Comment continued: A. J. Turner D. J. Jacob J. Benmergui S. C. Wofsy J. D. Maasakkers A. Butz O. Hasekamp S. C. Biraud (2016). A large increase in U.S. methane emissions over the past decade inferred from satellite data and surface observations, AGU100, Open Access – On-line, 06 February 2016, https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2016GL067987 Brooks, Amy. L, Shunli Wang and Jenna R. Jambeck (2018). The Chinese import ban and its impact on global plastic waste trade, Science Advances 20 Jun 2018: Vol. 4, no. 6, eaat0131, DOI: 10.1126/sciadv.aat0131. Coolsweep (2017) REPORT D 1.2 Global analysis of the Waste-to-Energy field, European Union 7th Framework Programme, accessed 1/2/2020 at https://www.waste.ccacoalition.org/document/global-analysis-waste-energy-field Geyer, Roland, Jenna R. Jambeck and Kara Lavender Law (2017) Production, use, and fate of all plastics ever made, Science Advances 19 Jul 2017: Vol. 3, no. 7, e1700782, DOI: 10.1126/sciadv.1700782 Gulf Petrochemicals and Chemicals Association [GPCA] (2014). A New Horizon for the GCC Plastic Processing Industry. Compiled by Nexant Energy & Chemical Advisory Services. Accessed 3/6/2016 at https://gpca.org. ae/2015/01/12/a-new-horizon-for-the-gcc-plastic-processing-industry/ Holden, Emily (2019) Will a push for plastics turn Appalachia into next 'Cancer Alley'? Will a push for plastics turn Appalachia into next 'Cancer Alley'? he Guardian, accessed 1/2/2019 at https://www.theguardian.com/environment/2019/oct/11/plastics-appalachia-next-cancer-alley-fracking-public-health-ethane Jambeck, R. Geyer, C. Wilcox, T. R. Siegler, M. Perryman, A. Andrady, R. Narayan, K. L. Law, Plastic waste inputs from land into the ocean. Science 347, 768–771 (2015), DOI: 10.1126/science.1260352..... Sanderson, Paul (2018) Bans on plastic recycling imports put in place in Vietnam and Thailand: paper restrictions too, June 22 2018. Website accessed 2/2/2020 at https://www.rebnews.com/bans-on-plastic-recycling-imports-put-in-place-in-vietnam-and-thailand-paper-restrictions-too/ .....UNEP (2019) Waste Management Outlook for West Asia, Authors: Ihab Tarek, Abdul Sattar Nizami, Paul Dumble, UN Environment Programme, p146, ISBN No 978-92-807-3767-7. "		Paul Dumble	Paul's Environmt Lentd	United Kingdom (of Great Britain and Northern Ireland)
25049					Replace "fossil fuel CO2" with "energy-related CO2"	Rejected/Accepted. It is important to distinguish where emissions are direclty derived from fossil fuels. At the same time, when we are discussing emissions that go beyond fossil fuels, this will be noted and a broader terminology will be used.	Eleni Kaditi	Organization of the Petroleum Exporting Countries (OPEC)	Austria
25051					Preferable to use the same units across the different figures	Accepted	Eleni Kaditi	Organization of the Petroleum Exporting Countries (OPEC)	Austria

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25523					Please take care not to use value-judgement terms such as 'important', 'significant' and also prescriptive terms such as 'need' and must'. Some readers will interpret these statements as policy prescriptive.	Accepted/Rejected. We are comfortable using words like important and significant, just as we are comfortable including some topics and not others in this chapter, which is an implicit statement of what is or is not important or significant. We are also comfortable using must and need when these are conditioned on particular outcomes and are justified by the literature. At the same time, we will remove must and need in cases when they are clearly not backed by the underlying literature and science	Sarah Connors	IPCC WGI TSU	France
25557					As a reader who isnt familiar with all the topics being discussed in your chapter, it might help many Exectutive Summaries to include subheadings to cluster the statements by topic or overarching chapter themes.	Rejected. The ES should be comprehensive and cross-cutting to the extent possible.	Sarah Connors	IPCC WGI TSU	France
26227					Overall, the chapter underestimates (or better, forget to mention) the substantial role CCS can play in the industrial sector, to address both combustion and process emissions	Rejected. This is a topic for the industry chapter	Sara Budinis	International Energy Agency	France
29279					There are a few passing mentions of off-grid in the report, but is there any potential for micro-grids and other off-grid systems to be part of future energy systems?	Rejected. Due to space constraints, we have not focused on micro-grids. However, this is an important point. Microgrids are important to consider both for facilitating a transtion to lower-carbon energy systems and for addressing the resiliency of these systems. We will reconsider this issue for the final draft as we assess room to add a box or paragraphs.	Vanesa Castan Broto	University of Sheffield	United Kingdom (of Great Britain and Northern Ireland)
34157					Estimates of the carbon cost per kwh could be added to each energy subsection in part 4 as it is one of the most important informations in a carbon emission mitigation logic. Or a sort of table like this one from a previous report : https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_annex-iii.pdf#page=7 [suggestion ENSEEIHT INP]	Noted. This is an interesting idea. We would also encourage a consideration of this in the Annex. At the same time, it is important to note that we are interested in this chapter not in the current carbon costs of technologies but rather what they might be in very different, low-, zero-, or negative-emissions future energy systems.	Antoine BONDUELLE	Climate Action Network France	France
34813					Check all the figures, tables and boxs to be sure are propoerly inserted. As it is, they mostly inserted into two pages.	Accepted	Onema Adojoh	Missouri University of Science and Technology, Rolla, USA	United States of America
35475					This chapter is ill-served by lengthy considerations on nuclear at odds with the real world situation and perspective of this source of energy, and a lack of peer-reviewed sources other than IAEA (pages 22, 39 to 41).	Taken into Account . We have substantially revised the section on nuclear power.	Charlotte MIJEON	Réseau "Sortir du nucléaire" - member of the French Réseau Action Climat	France
39073					SPLIT of CCUS (COMMENT 3/6) : CCS versus CCU as climate mitigation options: CCS is seen worldwide as a technology in the global portfolio of mitigation options that can contribute to mitigation and is taken into account in many climate scenarios based on the Integrated Assessment Models (IAM's). However, significant drawbacks exist about CCS options amongst which the risks associated to geological storage, the possibility of leakages, long-term liability issues, problems with public acceptance of onshore storage locations and limited cost-effective storage capacity in some essential regions (Styring et al., 2011, Bruhn et al., 2016, Arning et al., 2019). To date, the IAM's have 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, CCU technologies are unfairly considered to have limited and predominantly indirect abatement potential and are not discussed as mitigation options in the different IPCC reports. As stated in the Annex C of this first order draft, IAM's are missing important dynamics, e.g. with regard to carbon dioxide removal (Smith et al. 2016), rapid technological progress in the renewable energy sector (Creutzig et al. 2017), actor heterogeneity, and distributional impacts of climate change and climate policy. This has given rise to criticism that IAM's lack credibility in set of crucial assumptions, among which stands out the availability of carbon dioxide removal technologies (Bednar et al. 2019; Anderson and Peters 2016). This recognized failure of the IAM's to represent specific technologies should not prevent the integration of updated scientific discussions on all existing important technologies to mitigate climate change. It should also be noted that Energy System Models (EMS) are able to simulate the major CCU routes and other specific technologies and therefore a discussion on EMS and on their key results should be added in the report (e.g.Ram et al., 2019, Krey et al., 2019).	See Response to 39069	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
39073					Comment continued:The capture and conversion of CO2 into valuable products require the use of important renewable energy sources, an aspect that is often considered as a drawback to use these technologies. However, the prices of the different renewable energy options as well as an adequate evaluation of the future evolution of these prices (especially the cost of the solar energy) is crucial to assess the viability and climate mitigation potential of CCU technologies (Creutzig et al., 2017, Breyer et al., 2019, Haegel et al., 2019, Vartiainen et al., 2019, Krey et al., 2019). Even if no exhaustive quantification exists today on the mitigation potential of CCU technologies, the key role of this concept should be considered as one building block in a portfolio of mitigation measures (e.g. GCI, 2016, Grüber et al., 2018, IEAGHG, 2019b, Detz and Zwaan, 2019). CO2 utilization will contribute to curbing CO2 emissions with an estimated potential impact of gigatons equivalent CO2 emissions, similar or even superior to the impact of CCS and biofuels, but with a lower cost for society (Ampelli et al., 2015). 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 (GCI, 2016). Moreover, the key role of CCU as a vector to move away from fossil fuel resources and the potential move to a CO2 circular economy should be recognized and discussed adequately in the IPCC AR6 (e.g. Bruhn et al., 2016, Daggash et al., 2018).		Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
39075					SPLIT OF CCUS (COMMENT 4/6): Incentives and Policies Framing CO2 as a problem often translates into policies that hamper the implementation of technologies to decrease the amount of CO2 emitted into the atmosphere. Levänen and Hukkinen (2019) suggest that plurality in framing CO2 could lead to innovative ways and strategies to combat climate change. There are currently very few economic incentives for the deployment of CCS. In the future, however, regulation such as emission performance standards could make CO2 removal mandatory. Noteworthy, CCS is functional to a linear economy, whereas utilization of carbon dioxide is at the hearth of a circular economy and its strategic role will grow in the future (Zhu et al., 2019). For CCU, individual business cases are already providing incentives for different actors today. A higher price for emission allowances could further strengthen the incentives for both CCU and CCS (Bruhn et al., 2016, Castillo-Castillo 2019). CCU likely represents a promising perspective for contributing to climate mitigation efforts but considerations of CCU in climate scenarios and in politics need to account for the largely varying and technology specific features of each type of technology and sector. Moreover, the key role of CCU as a vector to move away from fossil fuel resources should be the first point highlighted. Hepburn et al, 2019 shows that 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 ton of CO2—increasing over time—to penalize CO2 emissions and to incentivize verifiable CO2 emissions reductions and removals from the atmosphere. The European SCO2T project concluded that CCU can make important contributions in Europe, by becoming a significant component in the future low-carbon circular economy and facilitating the energy transition (Wilson et al., 2016).	See Response to 39069	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
39077					SPLIT OF CCUS (COMMENT 5/6): Public acceptance: CCS projects have attracted considerable local opposition over the last decade (e.g. Brunsting et al., 2011; L'Orange Seigo et al., 2014). Therefore, using the term CCUS, especially considering the low public knowledge about CO2-based technologies (L'Orange Seigo et al., 2014; Perdan et al., 2017a), may transferred the negative vision of CCS to CCU and affect its perceptions and acceptance. A general public survey in Germany has demonstrated that CCU was perceived significantly more positively when it was properly considered (Arning et al., 2019).	See Response to 39069	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
39079					SPLIT OF CCUS (COMMENT 6/6): Added value: In the case of CCS, the added value is negative due to the costs of capture and storage and the increased primary energy demand. In the case of CCU, added value can be positive as a result of the cost savings from fossil raw material reduction. If the capture costs can be minimized, CO2 can be given a value and transformed from a liability into an asset (Bruhn et al., 2016, Krey et al., 2019). The existing literature shows that the current benefits of CCU are numerous (VITO, 2018). CCU can: • Decrease CO2 emissions at relatively short-term • Replace fossil or biobased feedstock • Defossilize the process industry and transportation sector • Store energy • Contribute to a circular economy • Create a revenue stream for CO2 abatement from fossil fuel use based on consumer demand for CO2-containing products. • Be an alternative for CCS • Improve Energy security • Make use of specific attributes of CO2 in commercially competitive applications • Remediate inorganic wastes from industrial processes • Sequestrate significant quantities of CO2 in building materials • Provide revenues to fund (partially) CCS projects • Reduce the complexity of chemical reaction pathways • Control the cost for the supply of fuels • Relocalize the energy supply	See Response to 39069	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
39081					THE CONCEPT OF POWER TO X :In the first order draft of the AR6 WGIII, the discussion about alternative fuel largely focuses on hydrogen and very little on the other alternative fuels, e.g. power-to-fuel. Only the term “power to gas” is shortly cited once, but without further explanation or discussion while it is a broad and generic term that has various types of applications and implications (Mathiessen et al. 2015, Ram et al., 2019, Fasihi et al, 2019). According to its importance in the energy transition, an exhaustive definition of Power to fuel should be given in this chapter with a discussion on the availability of each type of alternative fuels in taking into account the timeline and sectors in which they could be used for. To reach the goal of net zero emissions, fossil fuel-based energy demand could be mainly replaced by renewable electricity (RE) (e.g. DENA, 2017, Ram et al., 2019). However, there are sectors such as aviation, shipping, heavy transportation, energy intensive industries for which hydrocarbons cannot be replaced by electricity easily, or physically not at all (e.g. Fasihi et al., 2017, Hepburn et al., 2019, SDSN &FEEM, 2019). Biofuel production is faced with resource limitations and conflicts with food production and, therefore, offers no sustainable substitute (Koizumi et al., 2015, Tomei et al., 2016). Net zero emissions could be achieved by a defossilization of the energy system, whereby carbon from fossil sources is replaced by that which is created synthetically and sustainably from CO2 with the aid of RE. These CO2-based fuels can be emission neutral and be used in the current fossil fuel-based infrastructure (DENA, 2017, Fasihi et al., 2017, Artz et al., 2019, CONCAWE, 2019). Power to fuel is the concept enabling the production of hydrocarbon fuels (e-fuels) using RE. Two types of fuels can be generated: 1) Synthetic gas (e.g. e-methane) so-called Power-to-Gas and 2) Liquid fuels (e.g. methanol, ethanol), so-called Power-to-Liquid. In both cases, CO2 and green H2 (i.e. hydrogen generated by the electrolysis of water with RE) produce e-fuel (e.g. Breyer et al., 2015, Sternberg and Bardow, 2015, Dimitrou et al., 2015, Fasihi et al., 2017, Anwar et al., 2020). These e-fuels can be stored, transported and use as such or to produce electricity again. Liquid e-fuels are easier (and relatively inexpensive) to store and transport compared to electricity.	Same as 39069	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
39081					Comment continued: They can be kept in large-scale stationary storage over extended periods, and mobile storage in vehicle tanks, which can compensate for seasonal supply fluctuations and contribute to enhancing energy security (CONCAWE, 2019). Artz et al., 2019 has 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 in so called "Power-to-fuel" scenarios. Using power-to-fuel to meet the expected remaining fuel demand for aviation in 2050 would require renewable electricity equivalent to some 28% of Europe's total electricity generation in 2015. However, with today's technology, synthetic fuels are the only technically viable solution that would allow aviation to exist in a world that avoids catastrophic climate change" (Transport and Environment, 2018) The long-term use of carbon based energy carriers in a net zero emissions economy relies upon their production with renewable energy for low-cost, scalable, clean hydrogen production—for example via the electrolysis of water. The estimated potential for the scale of CO2 utilization in fuels varies widely, from 1 to 4.2 Gt CO2 yr−1, reflecting uncertainties in potential market penetration. The high end represents a future in which synthetic fuels have sizeable market shares, due to cost reductions and policy drivers. The low end—which is itself considerable—represents very modest penetration into the methane and fuels markets, but it could also be an overestimate if CO2-derived products do not become cost competitive with alternative clean energy vectors such as hydrogen or ammonia, or with direct sequestration (Grinberg Dana et al., 2016, Byrnolf et al., 2018, Hepburn et al. 2019, Anwar et al., 2020).		Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
39081					Comment continued: In the current version (First Order Draft) of the AR6 WGIII, the main focus of the discussion is about hydrogen when it comes to alternative fuels. 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, EU report, 2018). 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 CO2 based fuels, e.g. (Gumber and Gurumoorthy, 2018). 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) Shih et al. (2018) have demonstrated how harnessing solar radiation holds the answer to reducing our dependence on fossil fuels. The efficient conversion of solar radiation into stable, energy dense liquid energy carriers that can use existing or adapt global supply chains for storage, shipping, and distribution is the key to large-scale deployment of solar energy at gigaton levels. Liquid sunshine is the vision of combining the sun's energy with carbon dioxide and water to produce green liquid fuels (e-fuels). CO2 released on using these fuels is recycled back into the environment, thus maintaining an ecologically balanced cycle. Multisource and multi-purpose alcohols are optimal candidate fuels. Methanol and ethanol are actionable first targets with gigaton production potential. Sharma and Maréchal, (2019) propose a brilliant alternative to reduce CO2 emissions from the transport sector in capturing CO2, directly on board vehicles. Their CO2 capture system for engine exhaust stream (car, truck, bus, ship, or train) can capture 90% of the emitted CO2, without any energy penalty. This system can be integrated into overall mobility systems (fuel-engine- CO2 -fuel), where captured CO2 can be recycled as conventional liquid or gaseous fuels produced from renewable energy sources.		Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
39165					This chapter is too focused on existing electricity demand. The important role of electrifying other end-use sectors, such as transport, heating and industry, need more space. The effects of transport electrification, industry electrification and power-to-heat on the electricity demand (both in terms of higher electicity usage and more flexibility) needs its own section, see e.g. review https://doi.org/10.1016/j.energy.2017.05.123.	Rejected/Accepted. Treatment of industry and transport are largely covered in those chapters. At the same time, it's important for this chapter to assess the full system integration with the demand sectors.	Tom Brown	Karlsruhe Institute of Technology	Germany
39167					The view of the literature is narrow and misses much of the energy system modelling literature. There is generally too much self-citing by the authors and not enough coverage of sector-integration from continental Europe (Germany, Denmark, etc.), see e.g. https://doi.org/10.1016/j.energy.2017.05.123.	Accepted. Improving references	Tom Brown	Karlsruhe Institute of Technology	Germany
43149					General comment: I consider that this chapter should be expanded or be more specific in the impact of the energy systems in all the production and consumption baselines of human beings. The impact that energy has, for example: on food security, migration, emergencies such as the coronavirus where quarantine implies more consumption and efficiency in homes. Likewise, the impact of the interests of the powers in the Arctic on the extraction of gas or oil, given that it is not only that sea levels rise or polar bears will die.	[Taken into Account. We have included expanded and revised treatments of the way that mitigation interacts with broader soceital priorities.] [Rejected. Space limitations prevent us from discussing resource extraction in the arctic and the implications for polar bears.]	Antonethe Castaneda	UNESCO CONT E ECT	Guatemala

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43979					Chapter uses terminology like CCUS that is useful but unexplained until later in the chapter and different from (unknown to) other chapters. In terms of technologies the specific discussion should also include synthetic fuels more widely and mention those at the horizon and with open questions such as hydrogen production through photolysis, wave energy, CO2 emission-free hydrogen from fossil gas through pyrolysis (yielding solid carbon) etc., not to forget more detail on improved energy storage, e.g. battery technologies or storage of synthetic gas, and projected time scales of implementation for all. A comprehensive table may be warranted.	Taken into Account. We have revised the noted dsicussions accordingly.	Hans Poertner and Elvira Poloczanska	Alfred-Wegener-Institut	Germany
43981					Discussion of ecological impacts of renewable energy systems with regional differentiation, including impacts on individual species should be widened and connected to risk assessment of mitigation technologies, e.g. joining forces with WGII for a balanced treatment in the context of climate impacts and vulnerabilities. A comprehensive table may be warranted.	Accepted. We are expanding the treatment of broad "feasibility" characteristics of all technologies. A separate table just for renewable technologies is not in the offing, however, given space constraints.	Hans Poertner and Elvira Poloczanska	Alfred-Wegener-Institut	Germany
43983					chapter discusses demand side responses as crucial elements in the transition, however, production side responsibilities should also be mentioned and integrated into a holistic picture.	Noted. We do not understand what this comment means. The chapter is largely focused on energy production.	Hans Poertner and Elvira Poloczanska	Alfred-Wegener-Institut	Germany
44089					Figures 6.11, 6.12 and 6.16 resolution have to be enhanced.	Accepted	Mohammad Fahmy Ramadan	Head of Civil & Architecture Branch, MTC, Cairo, Egypt	Egypt
45441					There are good renewable energy figures in IRENA - can you use	Accepted. We use IRENA information in the chapter	Girija Parthasarathy	Thermo King	United States of America
45455					What is the feasibility of a hydrogen or ammonia economy given the technological, scale-up, societal (e.g.safety concerns) challenges to be overcome? As compared to an electrified economy.	Accepted: We have inserted an entire box on the concept of the hydrogen economy.	Girija Parthasarathy	Thermo King	United States of America
45473					There are numerous acronyms used throughout the report that are not expanded when first introduced or anywhere in the report. Switching back and forth between the report, glossary and definitions documents is difficult and makes is more difficult to provide substantive comments.	Accepted	Girija Parthasarathy	Thermo King	United States of America
45475					There are numerous figrues and tables provided throughout the report that are not referenced/explained in the report directly, or are lacking legends/titles/labels: these also detract from reviewing the contents of the report.	Accepted	Girija Parthasarathy	Thermo King	United States of America
46123					There was no mention of microgrids and distributed energy resources as some of the technological pathways for integrating variable renewable energy, providing decentralized balancing options as well as an energy system solution to vulnerable communities faced with climate change driven natural disasters.	Rejected. Due to space constraints, we have not focused on micro-grids. However, this is an important point. Microgrids are important to consider both for facilitating a transtion to lower-carbon energy systems and for addressing the resiliency of these systems. We will reconsider this issue for the final draft as we assess room to add a box or paragraphs.	Girija Parthasarathy	Thermo King	United States of America
46125					It is a monumental task to write and compile these reports. Suggestions for the structure the report to make it flow/read better: combining 'mitigation options' section with 'key characteristics of carbon-neutral energy systems', and transitioning into the next section 6.7. Otherwise some of the contect seems repeated. Another suggestion: the executive summary provide a 1:1 highlight from each large section, or at least structure the summary to refer to each large section.	Rejected. We are comfortable with the current structure, but it certainly needs to be implemented better in the SOD.	Girija Parthasarathy	Thermo King	United States of America
48025					Comments on the outline : section titles read as summaries of key findings (nice, but very different from other chapters).	Noted	Valérie Masson-Delmotte	CEA, IPSL/LSCE	France
48027					Comments on ES : could the ES be more specific on recent trends, separating coal, gas and oil?	Taken into Account / Rejected. Space limitations prevent a discussion of each of these fuels, but we have highlighted the importance of quickly phasing out coal	Valérie Masson-Delmotte	CEA, IPSL/LSCE	France
48029					Missing use of calibrated IPCC language to report key findings in ES	Accepted	Valérie Masson-Delmotte	CEA, IPSL/LSCE	France
48033					I see a need for coordination with WGI, especially chapter 12 ("climate information for impact and risk assessment") (eg information for heating and cooling demand, information / impact drivers / regions) to help better integrate across WG (quantitative / regional aspects / different time horizons?)	Noted. Not relevant to this chapter	Valérie Masson-Delmotte	CEA, IPSL/LSCE	France
48035					Coordination with WGI is also needed for commitment (geophysical + infrastructure aspects)	Accepted. We have conducted some modest integration with WG1 on climate impacts on energy systems	Valérie Masson-Delmotte	CEA, IPSL/LSCE	France
176					Figure 6.8 is not cited in the text.	Noted. All figures will be properly numbered	Lim Yun Seng	Universiti Tunku Abdul Rahman	Malaysia

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
27821					I am slightly unsatisfied by the excess confidence in renewables of the draft, and by the difficulty of the authors to imagine a contribution of nuclear pawer else than stabilizing the renewables. p. 12, l.26. you should add that "in the same time, the electric prodution raised froem ~6,000TWh to 26,000TWh, a factor 4.3,initiating a transfer to electric medum" p. 12 l. 34 "the share of nuclear power..". The nuclear power is 10% of electric generation (2700TWh in 2019, which is 10EJ). If compared to primary energy, it is three times more (33% efficiency), so it is 30EJ, and the world primary energy consumption is ~540EJ. So NP is not 1%, but close to 5.5%. I suggest the sentence: "Though the Fukushima accident, the nuclear primary energy is ~30EJ, i. e. still 5.5% of the total primary energy in 2020 (~540EJ)". You have to compare things that are comparable: If I read Fig. 6.6, there is a negligible part of nuclear in 1971: how can you tell that nuclear was 5% then????	Rejected. This is a conclusion of the experts based on the literature review and their respective expertise. Page 12 line 26 is on TPES. There might be a confusion if we introduce here electricity generation which is also from transformation. There are figures on electricity generation in the chapter. No need to repeat.	Frédéric Livet	CNRS-France	France
27823					p. 13 l. 2. You tell that "3two countries for coal and nuclear", but in Fig 6. 7, France+USA is less than 50% for nuclear, we need to add half of China to reach 50%...	Accepted.	Frédéric Livet	CNRS-France	France
27825					p. 17, line 17. Insert the following text: "The replacement of nuclear with Natural Gas (NG) can have detrimental effects to the climate. This may occur in Belgium, where the nuclear phase out is planned in 2025 and where the parliament recently voted subsidies for NG plants".	Noted. While nuclear phaseout provides larger context in certain regions, this section focuses on coal phaseout only. Added one sentence for regional context in the second draft.	Frédéric Livet	CNRS-France	France
27827					p. 21 l. 26 "Nuclear power has been declining": it is not true. In 2019, the NP electric production inceased of ~100TWh to 17,000TWh (10%) of electricity, partly from new power plants in China. This is correctly said in the following, but (p.22, l. 7) there is no nominal design for NP. In France, there is an eveluation every 10year, in the US it is 20 years and some are preparing to last 80 years.	Noted.	Frédéric Livet	CNRS-France	France
27829					p. 22 l. 35. China plans to add 6 (~7GW, Hualong 1) new reactors annually in the future. So it is not reasonable to write; ", suggesting...deployment falls short of its potential". I propose to suppress this opinion.	Noted.	Frédéric Livet	CNRS-France	France
27831					p. 24, l. 2. I propose to add: "It seems difficult to have a massive deployment of electricity storage before 2040, and it is subject to some hazard. For thie reason, premature closing of non-emitting controlled powes plans like nuclear can have adverse effects on GHG emissions."	Noted. This section focuses on recent trends. More discussion on storage including future projections in section 6.4.3	Frédéric Livet	CNRS-France	France
27833					p. 33 l. 33. We should add a oaragraph on the debates about EROI: "[Debate] There is an unresolved debate on the Energy Return Of Interest (EROI) of PV, where some estimates (Feroni et al. 2016) give an EROI smaller than unity and others are in the factor nine range (Koppelar, 2017)." Here the refences to be added are: F. Ferroni and R. J. Hopkirk, Energy Policy 04 (2016), p. 336-344 R.H.E.M.Koppelaar, Renewable and Sustainable Energy Reviews 72 (2017), p. 1241-1255	accpted - new section on lifecycle analysis added, including section on EROI.	Frédéric Livet	CNRS-France	France
27835					p. 35, l 8-13. I think that you have excess enthousiasm about the improvements of wind industry. I attach a file from a paper (Linnemann, 2017) reference: T. Linnemann and G. Vallana(2017). "Wind energy in Germany and Europe Status, potentials and challenges for baseload application -1- Developments in Germany since 2010". Atw Internationale Zeitschrift fuer Kernenergie, 62(11) (2017), p.678-688. about Denamrk (l. 13): in 2017, Wikipedia gives 14.8TWH and 5.47GW, which is 31%, and in 2010 I find 24%. It now includes a lot of onshore. I thing that 39% in onshore is wrong, as well as 27% in 2010. see: https://en.wikipedia.org/wiki/Wind_power_in_Denmark Here, it seems difficult to have a scientific distance with propaganda.	Taken into Account. The paragraph has been removed, so this comment is no longer relevant.	Frédéric Livet	CNRS-France	France
9221					Figure 6.17 Global map of gross hydropower potential distribution (clear & representative).	Noted.	Mounir Wahba Labib Risk	National Academy of Science, Egypt	Egypt

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27837					p. 40, l. 48 and p. 41; l1. In France, load following is practiced since the beginning and no additional investments are necessary. In Germany, all nuclear will close. So I suggest to change the sentence: "Nuclear power plants are well experienced in France in operating in a flexible manner to provide these services. Nthertheless.."	Rejected. It refers to the experience of operating nuclear reactors in a flexible manner.	Frédéric Livet	CNRS-France	France
27839					p. 41, l. 5 "Nuclear power contributes to climate" Obviously, it remains modest, but Why do you add "can"??? It is still more than Wind and PV.	Noted. "Can" in this sentence affirms nuclear ability to contribute to climate change mitigation. Following sentence mentions that however this and other benefits of nuclear are not properly reflected in policies, etc.	Frédéric Livet	CNRS-France	France
27841					p. 42, l. 6. I should like to add a paragraph: 'There are concerns in the prematurate closing of nuclear power plants (MIT, 2018), where MIT shows that Natural Gaz will be the "winner" for the replacement of ancient nucelar plants." reference: energy.mit.edu/research/future-nuclear-energy-carbon-constrained-world	Accepted. Text revised.	Frédéric Livet	CNRS-France	France
9223					Figure 6.18 Estimated Shares of Bioenergy in Total Final Energy by End-Use Sector, 2017 (clear & representative)	Accepted. Text modified	Mounir Wahba Labib Risk	National Academy of Science, Egypt	Egypt
9225					Figure 6.19 This estimate from (Bhave et al. 2017), (Not Clear, and needs more clarifications).	Accepted. Text modified	Mounir Wahba Labib Risk	National Academy of Science, Egypt	Egypt
9227					Figure 6.20 Illustration from (Smith 2016), (Not Clear, and needs more clarifications).	Accepted. Figure has been removed	Mounir Wahba Labib Risk	National Academy of Science, Egypt	Egypt
9229					Figure 6.21 Geographical distribution of oil and gas resources. (Not Clear, and needs more clarifications).	Taken into account. A separate box is devoted on fossil fuel subsidies.	Mounir Wahba Labib Risk	National Academy of Science, Egypt	Egypt
9231					Figure 6.22 Costs of production for (a) oil, (b) gas and (c) coal as a function of recoverable resource (Not Clear, and needs more clarifications).	Noted.	Mounir Wahba Labib Risk	National Academy of Science, Egypt	Egypt
9233					Figure 6.23 Global weighted average total installed costs, capacity factors and LCOE for geothermal power, 2010 (Not Clear, and needs more clarifications).	Accepted. Comment will be added to the figure..	Mounir Wahba Labib Risk	National Academy of Science, Egypt	Egypt
9235					Figure 6.24 Global WtE Market revenue by technology, 2014-2024 (clear & representative)	The figure has been repalced with texts.	Mounir Wahba Labib Risk	National Academy of Science, Egypt	Egypt
27843					p. 54, line 20: one needs estimate of cycle efficiency (electricity-storage-electricity) . I give values for this cycle (as far that they can provide electricity). p. 55 line 9: efficiency of the cycle: 60-70% line 24: efficiency: 30-60% p. 57, line 2: efficiency with Li batteries: 90% line 19: efficiency ~90% Line 33: efficiency <30% p. 59 line 2: efficiency 50%	Added a row to table 6.51	Frédéric Livet	CNRS-France	France
27845					p.60, table 6.74. Electrolysis is in the 60-70% efficiency range with present technologies. There are no "solid electrolysers" active, and the cycle of these electrolysers is difficult to discuss (you have to work at 800-900°C..) Your cost estimates of water electrolysis also seem very low. These times, it seems to be in the range 5-10€/Kg, i. e. 130-250£/MWh. I recall that half of the price is electricity (1.5MWh/MWh hydrogen) and the other half is the electrolyser price itself. I suggest to change to ~150£/MWh. 90£ is too low. You must be careful with too optimistic papers.	Thanks for the comment. This part is completely revised and a detailed table on different electrolysis technologies is provided: Table 6.75: Efficiency and cost characteristics of different hydrogen production through electrolysis technologies	Frédéric Livet	CNRS-France	France
27847					p. 61 line 3 "to Europe AND JAPAN.." there are big japanesse projects: https://www.japantimes.co.jp/news/2018/04/12/business/consortium-import-australian-hydrogen-japan/#.WvtH-ke4bIo I wrote a beautiful paper about this (in French): https://www.sauvonsleclimat.org/fr/base-documentaire/hydrogene-japon	Thanks for the sugestion. Here we tried to provide just an example and hence mentioned europe. Beside I tried to access the link that you provided, but unfortunately it is expired.	Frédéric Livet	CNRS-France	France
9237					Figure 6.25 Ammonia and hydrogen production, transport and utilisation (clear & representative)	The whole section is enhanced and the figure is updated. The numbering would be updated at the end once the complete file is finalised	Mounir Wahba Labib Risk	National Academy of Science, Egypt	Egypt
9239					Figure 6.26 Spatial intensity of the wind (Global Wind Atlas 2019) and solar (Global Solar Atlas 2019) power resources in Europe (clear & representative)	Noted	Mounir Wahba Labib Risk	National Academy of Science, Egypt	Egypt

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9241					Figure 6.27 Transition to future smartly integrated low carbon energy system (clear & representative)	The numbering would be updated at the end once the complete file is finalised	Mounir Wahba Labib Risk	National Academy of Science, Egypt	Egypt
9243					Figure 6.28 System Integration Cost (SIC) of wind and solar in inflexible and flexible systems,(clear & representative)	The numbering would be updated at the end once the complete file is finalised	Mounir Wahba Labib Risk	National Academy of Science, Egypt	Egypt
27849					p. 73. Table 6-8. In Germany, the call of offers is ~62€/MWh for onshore wind, which is 70$. The german prices are usually the lowest. People estimate that coal (and brown coal) is less than 40$/MWh (without CO2 taxes). Nuclear in 2019 in France is less than 50€(58$)$. Only future nuclear can be more expensive.	Noted, these costs are discussed in section 6.4 for the relevant options	Frédéric Livet	CNRS-France	France
9245					Figure 6.29 Schematic representation of the effect of changes in various climate parameters (left) on energy generation (right). (clear & representative)	Accepted. A new figure/table replaces this figure.	Mounir Wahba Labib Risk	National Academy of Science, Egypt	Egypt
9247					Figure 6.30 Global spatial patterns of changes in gross hydropower potential based on climate forcing from five GCMs. (clear & representative)	noted	Mounir Wahba Labib Risk	National Academy of Science, Egypt	Egypt
27851					p. 76 l. 26 "..on local ans regional climate (Lundquist et al 2017) AS WELL AS WAKE EFFECTS (Miller 2016)(Plattis 2018). references:) L. Miller and A. Kleidon, PNAS 113-48 (2016), p. 13570-13575 A. Platis et al. Nature Comm/Sci. Rep. 8 (2018) 2163	Taken into account. Such relationships are the topic of BOX ##.	Frédéric Livet	CNRS-France	France
9249					Figure 6.31 Total net global annual CO2 emissions (including energy, industrial processes, and non3 energy) and net non-energy emissions for all scenarios and years (clear & representative)	We refined the caption for this figure to be more descriptive.	Mounir Wahba Labib Risk	National Academy of Science, Egypt	Egypt
9251					Figure 6.32 Energy System from Davis et al. as an example of methods to address hard-to-electrify sectors. (clear & representative)	Unclear what comment is saying.	Mounir Wahba Labib Risk	National Academy of Science, Egypt	Egypt
28809					Section 6.6.27 explores CDR in the energy system. Currently, the text is underdeveloped and is vague only noting that CDR will have to play a role in a net-zero energy mix, that the technologies are underdeveloped and that different countries will likely have different capabilities and storage potential. The section would be improved by some examination of the assumptions underlying modelling that rely on CDR – i.e., some unpacking of how it will be delivered, governed and maintained over the long term.	Accepted. The section has been developed with detailed characteristics on some of the opportuties and challenges in delivering and regulating CDR.	Paul Rouse	Carnegie Climate Governance Initiative	United Kingdom (of Great Britain and Northern Ireland)
9253					Figure 6.33 The three levels of institutions (1-3) which collectively govern actor behaviors (4). Source: Andrews-Speed 2016 (clear & representative)	Noted. What is the comment here? It is just describing our figure	Mounir Wahba Labib Risk	National Academy of Science, Egypt	
27853					p. 96 Box 6-18 seems to me somewhat speculative. People can speculate for the 22nd century, but China-Europe interconnections are far future and the connections between Sahara and Europe seem abandoned (Desertec..).	Noted. The text is updated and more generalised:"Climatic dipoles present both regionally and on continental scales could also help support diversification of renewable energy sources and mitigation of risk due to complementary weather and climatic phenomena across Northern, Southern Europe and beyond, and e.g. even more locally such as between the North and South of the UK (Dawkins, 2019). Further integration between Europe and MENA could also have significant mutual economic benefit and support increasing decarbonisation, potentially significantly contributing to a fully decarbonised system by 2030 (Bogdanov et al., 2016). This is further investigated in (Breyer et al., 2019). Furthermore, west-east interconnection can enhance utilisation of renewable generation and further reduce cost of decarbonisation. Due to the different time zones, e.g., electricity from solar generation produced in Middle East (with higher capacity factors) could be used in Europe even after sunset, although geopolitical and socioeconomic challenges remain for international co-operation, as well as the techno-economic challenges associated with large-scale network expansion. As hydrogen may have significant role in decarbonisation of the energy sector in future, the generated electricity by solar or wind can be used to generate hydrogen through electrolyses process, and then shipped to other locations. There is significant interest in producing hydrogen in the North Sea by offshore wind generation and also in the Middle East by solar generation. Hence, there is growing interest in infrastructure for transport of hydrogen over both short and long distances.	Frédéric Livet	CNRS-France	France
9263					Figure 6.39 Global assessment of carbon lock-in risks by fuel and sector (Not Clear, and needs more clarifications).	Accepted. Additional details provided	Mounir Wahba Labib Risk	National Academy of Science, Egypt	Egypt
9265					Figure 6.40 Annual emissions from existing, proposed and future infrastructure (clear & representative)	Noted.	Mounir Wahba Labib Risk	National Academy of Science, Egypt	Egypt

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9267					Figure 6.41 (Mockup) Total primary energy use from 2010-2100 from fossil fuels (needs more clarifications)	Accepted. Additional details provided	Mounir Wahba Labib Risk	National Academy of Science, Egypt	Egypt
9269					Figure 6.42 Cumulative consumption of fossil fuels in various IAM results adhering to various scenarios.(not clear grapg, needs more clarifications)	Accepted. Additional details provided	Mounir Wahba Labib Risk	National Academy of Science, Egypt	Egypt
9271					Figure 6.43 Nature of the interactions between SDG7 (Energy) and the non-energy SDGs (impressive graph, but needs to be repeated in big graphs. I can't read the items in the two circles).	Accepted. The figure formatting has been modified.	Mounir Wahba Labib Risk	National Academy of Science, Egypt	Egypt
9257					Figure 6.36 Total energy supply investments across scenarios (Not Clear, and needs more clarifications).	Rejected. The reviewer's comment is not clear.	Mounir Wahba Labib Risk	National Academy of Science, Egypt	Egypt
9259					Figure 6.37 Annual average energy investment for fossil fuel supply, renewables, grid, energy demand, energy efficiency, and the other by region. (clear & representative)	Noted. The Figure is updated.	Mounir Wahba Labib Risk	National Academy of Science, Egypt	Egypt
9261					Figure 6.38 Annual average investments period 2010-2050.& Change in investment profile, 2030 (the data in the graph is not clear, needs more clarifications).	Rejected. The reviewer's comment is not clear. The data source is presented. (IPCC Scenario Database)	Mounir Wahba Labib Risk	National Academy of Science, Egypt	Egypt
27855					p. 98 l. 6 It seems to me that the subject was discussed in Chapter 3... p. 98, l. 28 "four time largeRRRR than.."	Partially accepted. p. 98, l. 28 is corrected. This section puts focus on "Energy System" transitions, whichi is diffrent from Chapter3.	Frédéric Livet	CNRS-France	France
39083					LIST OF REFERENCES FOR THE COMMENTS ON CCUS AND POWER TO X: • Aldaco et al., 2019, Science of the Total Environment, 663, 738-753. • Ampelli et al., 2015: CO2 utilization: an enabling element to move to a resource and energy-efficient chemical and fuel production, Phil.Trans.R.Soc.A, 373. • Anderson and Peters, 2016, Science, 354, 182–183. • Anwar et al., 2020, J. of Env. Manag., 260, 110059. • Arning et al. 2019, Energy Policy, 125, 235–249. • Artz et al., 2019: Sustainable Conversion of Carbon Dioxide: An Integrated Review of Catalysis and Life Cycle, Assessment, Chem. Rev., 118, 2, 434-504. • Ball and Weeda, 2015, International Journal of Hydrogen, 40/25, 7903-7919. • Bednar et al. 2019, Nat. Commun., 10, 1783. • Bodénan et al., 2014, Minerals Engineering, 59, 52-63. • Breyer et al., 2015, Energy Procedia, 73, 182-189. • Breyer et al., 2019, Joule, 3, 2053-2057. • Bruhn et al., 2016, Environmental Science & Policy, 60, 38–43. • Brunsting et al., 2011, Int. J. Greenhouse Gas Control 5, 1651–1662. • Byrnolf et al., 2018, Renewable and Sustainable Energy Reviews, 81/2, 1887-1905. • Castillo-Castillo, 2019, Policy analysis and recommendations for EU CO2 utilisation policies. In: CEST2017 15th International Conference on Environmental Science and Technology, Rhodes, Greece. • CCES, 2019: Carbon Utilization – A vital and effective pathway for decarbonization, Center for Climate and Energy Solutions. • Chen et al., 2016, J. of Cleaner Production, 124, 350-360. • CONCAWE, 2019: A look into the role of e-fuels in the transport system in Europe (2030–2050) (literature review), CONCAWE. • Creutzig et al. 2017, GCB, Bioenergy. • Cuéllar-Franca and Azapagic, 2015, J.CO2.Utili., 9, 82-102. • Daggash et al., 2018, Sustainable Energy Fuels, 2, 1153-1169. • DENA, 2017, The potential of electricity-based fuels for low-emission transport in the EU: An expertise by LBST and dena (German Energy Agency).	Taken into account. We have updated our references based on space available.	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
39083					Comment continued: • Detz and Zwaan, 2019, Energy Policy, 133, 110938. • Deutz et al., 2018, Energy Environ. Sci., 11, 331. • Di Maria et al, 2020: Environmental assessment of CO2 mineralisation for sustainable construction materials, International Journal of Greenhouse Gas Control, 93. • Dimitrou et al., 2015, Energy Environ. Sci, 8, 1775-1789. • Ebrahimi et al., 2017, J. of Cleaner Production, 156, 660-669. • EU, A Clean Planet for All, 2018: A Clean Planet for all A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy, Communication from the EU commission. • Farfan et al., 2019, J. Clean Prod., 217, 821-835. • Fasihi et al., 2017, J. of Cleaner Production, 224, 957-980. • Fasihi et al., 2019, Journal of Cleaner Production, 224, 957-980. • Fernandez-Dacost et al., 2017, J. CO2. Util., 21, 405-422. • GCI, 2016: Global Roadmap Study of CO2U Technologies, LUX Research & Global CO2 Initiative. • Giannoulakis et al., 2014, International Journal of GHG Control, 21, 140-157. • Gumber and Gurumoorthy, 2018, Methanol, Chap. 25, 661-675. • Geyer et al., 2017: Production, use, and fate of all plastics ever made. Sci. Adv. 3 • Grinberg Dana et al., 2016, Angew. Chem. Int. Ed. 2016, 55, 8798 – 8805. • Grüber et al, 2018: A low energy demand scenario for meeting the 1.5 C target and sustainable development goals without negative emission technologies', Nature Energy, 3, 6. • Haegel et al., 2019, Science, 364, 836-838. • Hepburn et al., 2019: The technological and economic prospects for CO2 utilization and removal, Nature, 575, 87-97. • Huang et al., 2019, J. of Cleaner Production, 241, 118359. • IEA, 2013, Technology Roadmap: Carbon Capture and Storage—2013 edition. OECD/ IEA, Paris. • IEAGHG, 2019a: Putting CO2 to Use – Creating value from emissions, International Energy Agency. • IEAGHG, 2019b: Exploring Clean Energy Pathways: the role of energy storage, International Energy Agency.		Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
39083					Comment continued: • IPCC Special Report 1,5degC, 2018: Special Report 1.5 – Summary for Policy Makers, Intergovernmental Panel on Climate Change (IPCC). • Jarvis and Samsatli, 2018, Sustain.Energy.Rev, 85, 46-48. • Kaliyavaradhan et al., 2017, J. CO2. Utili., 20, 234-242. • Kätelhön et al., 2019: Climate change mitigation potential of carbon capture and utilization in the chemical industry, PNAS, 116, 23, 11187-11194. • Khoo et al., 2011, Energy Procedia, 4, 2494-2501. • Kirchoffer et al., 2013, Energy Procedia, 37, 5858-5869. • Klankermayer and Leitner, 2015, Science 350, 629–630. • Koizumi et al., 2015, Renewable and Sustainable Energy Reviews, 52, 829-841. • Koytsoumpa et al., 2018, The Journal of Supercritical Fluids, 132,3–16. • Krey et al., 2019, Energy, 172, 1254-1267. • Lee et al., 2020, J. CO2. Util., 37, 113-121. • Levänen and Hukkinen, 2019, Global Sustainability, 2, e25. • L'Orange Seigo et al., 2014, Int. J. Greenh. Gas. Control 25, 23–32. • L'Orange Seigo et al., 2014, Renew. Sustain. Energy Rev. 38, 848–863. • Mathiessen et al. 2015, Applied Energy, 145, 139-154. • Metz et al., 2005, IPCC Special Report on Carbon Dioxide Capture and Storage. Cambridge University Press, New York. • Muratori et al., 2018, Energies 2018, 11, 1171. • NAS, 2019, Negative Emissions Technologies and Reliable Sequestration, The National Academies Press. • Nduagu et al., 2013, Applied Energy, 106, 116-126. • Nocito and Dibenedetto, 2020, Current Opinion in Green and Sustainable Chemistry, 21, 34–43. • Pan et al., 2020: CO2 Mineralization and Utilization using Steel Slag for Establishing a Waste-to-Resource Supply Chain, Nature Scientific Reports 7, 17227. • Pasquier et al., 2018, Geosciences, 8(9), 342.		Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
39083					Commnet continued: • Perdan et al., 2017, Sustain. Prod. Consum. 10, 74–84. • Ram et al., 2019 EWG&LUT, 2019: Global Energy System Based On 100% Renewable Energy, Energy Watch Group & LUT University. • Schemme et al., 2017, Fuel, 205, 198-221. • SDSN & FEEM, 2019: Roadmap to 2050 - A Manual for Nations to Decarbonize by Mid-Century, Sustainable Development Solutions Network & Fondazione Eni Enrico Mattei. • Sharma and Maréchal, 2019, Front. Energy Res. 7, 143 • Shih et al., 2018, Joule, 2, 1925-1949. • Smith et al. 2016, Nature Climate Change, 6, 42-50. • Sternberg and Bardow, 2015, Energy Environ. Sci. 8, 389–400. • Sternberg et al., 2017, Green Chemistry, 9. • Styring et al., 2011, Carbon Capture and Utilization in the Green Economy. Centre for Low Carbon Futures, York.		Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium