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

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
39085	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. 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).	CCU and CCS will be split. We will also make clear what examples of CCU we have in mind. People get different ideas, from taking coal power exhaust for greenhouses to our implicit idea of chemical recycling and closing the loop on carbon in chemicals. Note/underline CCS for cement!	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
39087	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).	Revisions will be made to make clear CCU versus CCS and that our focus is industry (and not so much about fossil fuel combustion in industry even). Rather about chemical recycling and such	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
44965	0		0		As a general comment: The chapter would benefit from a deeper look into stocks, lcok/ins and cumulative emissions effects.	Accepted.	Andreas Schroeder	International Energy Agency IEA	France
14279	0				Comment: There are different areas in the report (see page 38) where the term CCS is mistakenly used when the discussion is only about carbon capture technologies. I suggect to use only the term "carbon capture" when the discussion is on capturing emissions and not on their subsequent fate (utilisation or storage)	Accepted. Will be clarified	Anastasios Perimenis	CO2 Value Europe (Association) - CCU Offiver	Belgium
16345	0				For Chapter 11, consider adding a description of the role global military procurement plays in determining industrial processes for manufacturing goods and materials used by that sector, and the key influence that sector has in determining outcomes.	Rejected. To address this concern we need literature based on which first military part of industrial products may be allocated and second - associated emissions may be evaluated. There new stream of literature allowing to allocate industrial emissions to some final products (buildings, cars), but military products are not yet in focus of those.	Daniel Helman	College of Micronesia-FSM	Micronesia, Federated States of

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33173	0				I trust that there are over productions for many sectors. Limit to production policy can be justified. For example, behaviour aspect of food and clothing wastage may have implication to climate change. Inddiviual celling or limit can be applied. It could be even voluntarily for some next ten years which help to generate individual awareness	My apologies, but I don't completely understand what is meant by over-production. 11.6 is a large section. When supply and demand are out of balance, or when too much of a given good or service is made with strong externalities. We can't respond to this without understanding the comment.	Edris Alam	Rabdan Acadmey	United Arab Emirates
34523	0				I hope the authors will take it as a compliment that after reading the Exec Sum I decided I really should concentrate my review time on other chapters. To judge from the Exec Sum it is a superb chapter, really interesting, well structured and clearly presented. Congratulations.	Thank you.	Michael Grubb	UCL - Institute of Sustainable Resources	United Kingdom (of Great Britain and Northern Ireland)
34525	0				[and section 11.6.2]. From reading Exec Sum and skimming corresponding section, one specific suggestion is that the authors collectively consider more deeply how to approach the issues around carbon leakage, investment and 'border adjustments'. First, this could usefully be coordinated with Chapters 12 (discusses leakage estimation) and 13 (which has a section on BCAs) and/or 14. In Ch.11 it is located in a section on carbon pricing, which indeed is how almost all the literature addresses it, though the issue could arise from other policies which may raise costs. It would be useful to clearly distinguish the principles, notably, consumption-based measures and border carbon levelling, which are in principle non-discriminatory, vs potentially discriminatory trade measures. It could be useful if possible to set in wider context of trade and climate relationships. Pleased to see reference to Mehling et al, worth checking and citing the development of this work as now published in leading law journal: Mehling, M., Van Asselt, H., Das, K., Droege, S., & Verkuijl, C. (2019). Designing Border Carbon Adjustments for Enhanced Climate Action. American Journal of International Law, 113(3), 433-481. doi:10.1017/ajil.2019.22 It may be worth raising at WG level how AR6 should approach this issue across chapters.	Thank you, we have included Mehling et al 2019 in the SOD and expanded on our treatement of BTA/BCAs and of consumption vs. produciton pricing with respect to industry in 11.6.2.	Michael Grubb	UCL - Institute of Sustainable Resources	United Kingdom (of Great Britain and Northern Ireland)
44805	0				The reading of the Chapter is not fluid, repetitions make it heavier. Many statements appear without experimental references. Models should be added to validate the assertions.	Accepted. Will be fixed in the SOD	Véronique Waroux	Planète-A	Belgium
44807	0				Hydrogen is cited as a safe lead. Examples and references should be multiplied in order to convince, with evaluated profitability	The overall section 11.3.5 is well referenced with respect to energy carrier switching, and to hydrogen in particular. The hydrogen box may need some substantiation, and we will review that for the SOD.	Véronique Waroux	Planète-A	Belgium
44809	0				Better explain Biocarbon, Biogenic Carbon and BECCS. Explain the exergy analysis	Yes	Véronique Waroux	Planète-A	Belgium
44811	0				Shouldn't we integrate the possibility of recycling crushed concrete in reconstruction via 3D printers (e.g. projects by architect Vincent Callebaut)? The "healthy" nature of the binder used should be checked.	Recycling of crushed concrete and aggregates will be folded into the relevent sections in ths SOD.	Véronique Waroux	Planète-A	Belgium
44813	0				Isn't it appropriate to separate the concepts of Use and Storage in CCUS? --> CCU and CCS?	Yes. The reviewer's point is taken and we will be reviewing how we use the terms CCUS and CCS. The differenc will be defined in one place and used consistently thereafter.	Véronique Waroux	Planète-A	Belgium
8851	1	1	1	1	In the entire chapter, there is no mention of the role, potential, challenges related to small and medium enterprises (SMEs) and of industry supply chains. These should be more clearly discussed as they represent an important step for industry sector decarbonisation.	We do mention SMEs when we present the meso level, where we state:"This is crucial for those small and medium enterprises (SMEs) because they often lack access to information and lack funds to sophisticated technologies." We also added one more sentense later in this paragraphto further emphasizing the benefits of industrial symbiosis, stating "In particular, it can facilitate those small and medium sized enterprises to improve their growth and competitiveness." We also added one more sentence in the middle of this paragraph, saying " In particular, it can facilitate those small and medium sized enterprises to improve their growth and competitiveness since they can benefit from byproducts exchanges and improved infrastructure induced by industrial symbiosis."	Saygın Değer	SHURA Energy Transition Center	Turkey
17349	1	1	74	30	The report lacks a section on spatial-planning. Besides technology and processes, the zoning and site-selection of industrial activities, should be considered and addressed as a means of direct and indirect mitigations.	Rejected. The spatial planning issues are to be addressed in Chapter 8: Urban Systems and Other Settlements	Zeyaeyan Sadegh	Islamic Republic of Iran Meteorological Organization (IRIMO)	Iran
18509	1		78		an overall comment: in the industry chapter, there should be a discussion on zero carbon manufaturing sectors such as renewable energy sector, which will replace fossil fuel producing sectors. that means that there will be a shift of or restructuring of industrial sub-sectors. this would have significant implications for mitigation.	Accepted.	Jiahua Pan	Chinese Academy of Social Science	China

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8915	1	1	100	37	The different sections in the chapter include repetition of simliar aspects of climate change mitigation in industry. This is fine in general, but there are inconsistencies between the different sections on for example technology options for specific industries (e.g. between descriptions in 11.3 and 11.4) or policy instruments and their descriptions. The inconsistencies need to be adjusted and a reference to the section with the more comprehensive description/discussion would be useful for the reader.	Accepted. Will be fixed in the SOD with consistency check across sections.	Johannes Morfeldt	Chalmers University of Technology	Sweden
18499	4	4	4	6	the focus of this chapter is on materials industries. manufafcuring is not within such a category? the title of this chapter is industry, at least manufaturing such a textile, machinery, nd the like, should be included, ig tertiery and agriculture are not.	Accepted. While material production dominates the industrial emissions more attention will be given to other subsectors in the SOD	Jiahua Pan	Chinese Academy of Social Science	China
18501	4	6	4	6	the statement "net zero emissions from industriial sectoor is possible" may cause difficultieis in understanding. there is a need to see when and how. disappearance of industrial sector of cause is zero emission. 100 year later wneh everything is zero carbon, also OK. so it must see to what extent and how much and when.	Accepted. Clarification would be added.	Jiahua Pan	Chinese Academy of Social Science	China
13235	4	6	4	9	It should also be mentionned that promissing breakthrough technologies are being developed but few are proven at industrial scale until now	Accepted. Clarification would be added.	Asa Ekdahl	world steel association	Belgium
34455	4	6	4	9	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). (Cuéllar-Franca and Azapagic, 2015, J.CO2.Utili., 9, 82-102./Arning et al. 2019, Energy Policy, 125, 235–249./ Bruhn et al., 2016, Environmental Science & Policy, 60, 38–43)	Accepted. More attention would be given to differentiation between CCS, CCU, CCUS	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
45387	4	6	4	9	Could also mention "enablers could also be integrated, flexible and reliable processes, technologies and energy systems". Mention about flexible processes and technologies.	Accepted. Text would be revised	Shareq Mohd Nazir	KTH Royal Institute of Technology	Sweden
44815	4	9	4	9	CCUS is widely taken up as a solution but the use of CO2 is not (well) known so far.	Accepted. More attention would be given to differentiation between CCS, CCU, CCUS	Véronique Waroux	Planète-A	Belgium
15677	4	12	4	15	This overview of the share of emissions that are from industry is excellent. I appreciate the way you included both figures without and with indirect emissions. Great job. Note that in the case with indirect emissions, you mention both an emissions quantity (20 Gt) and a percentage of the global total (34.5%), while in the case without indirect emissions, you mention only the percentage of the global total (24.3%). To keep these sentences parallel, and so the reader doesn't need to do arithmetic, it would be nice to mention the abatement in the case without indirect emissions both in mass units (Gt) and the percentage of the global total.	Accepted	Jeffrey Rissman	Energy Innovation: Policy and Technology LLC	United States of America
6115	4	14	4	15	The statement " industry becomes a larger GHG emitter ……if indirect emissions from power and heat generation are included" is not clear. Is the group saying Power and Heat generation are under Industrial sector? What are the indirect emissions? Needs to be clarified.	Rejected. Indirect emission would be defined not in the chapter, but in the glossary.	Joseph Essandoh-Yeddu	Energy Commission	Ghana
34223	4	16	4	16	The definition of 'in-use stock' is complex and maybe it could be explained one time in the beginning of this chapter. [suggestion ENSEEIHT INP]	Accepted. Will be clarified	Antoine BONDUELLE	Climate Action Network France	France
46795	4	16	4	16	The evolution of energy intensity by sector and by type of energy is not well developed in the report. the expression "global energy intensity is declining" is very general. I think a more detailed study will be possible.	Rejected. Chapter space limit doesn't allow for detail discussion of energy efficiency indictors for all subsectors.	Luis Javier Miguel González	University of Valladolid	Spain
15679	4	16	4	18	You mention that "material intensity (in-use stock of manufactured capital per unit of GDP) is increasing" and has been increasing since 2000. This is fascinating. But I don't know why the global economy is becoming less material-efficient, even while it becomes more energy-efficient (and more labor-efficient). Do you think you could add a sentence, or a clause separated by a comma, explaining the reason why the global economy has been getting less material-efficient? This would help readers understand the cause of this counter-intuitive effect.	Accepted. There is some discussion in the text already. Additional clarification would be added.	Jeffrey Rissman	Energy Innovation: Policy and Technology LLC	United States of America
34457	4	20	4	21	This decoupling can be increased by material sufficiency and circular economy.	Rejected. Circular economy is represented via MSE parameter. As to sufficiency - this is the subject for chapter 5. In Chapter 11 we consider the demand for final products, which industry should produce as given.	Emmanuel RAUZIER	NGO Association negaWatt	France
33001	4	28	4	31	99% reliance on feedstock' is unclear. Around half the chemical sector's energy is consumed as feedstock. For plastics the share is higher, but I don't think it is 99%. If something else is being referred to here, then it needs to be clearer. Quoting the global plastic collection rate or some other relevant metric could be more useful than 'very low recycling'. It is true to say that much less plastic is recycled than steel or aluminium or asphalt, for example, but when you compare it to cement (0% proper recycling), the rate is high. 'There are yet no shared visions for fossil-free plastics' is misleading also - biomass and electrolytic hydrogen (plus an external carbon source for the latter) are potential ways to reduce fossil fuel inputs to plastics production, but indeed these alternatives are expensive and require enourmous inputs of bioenergy/renewable electricity.	Accepted. Will be checked	Peter Levi	International Energy Agency	France
13237	4	29	4	31	All of these materials are important for reducing emissions elsewhere and it is inappropriate to single out plastics in this respect. Either delete the sentence or add similar sentences for the other materials	Accepted. More balanced statement would be provided.	Asa Ekdahl	world steel association	Belgium
30905	4	31	4	31	Yes and no. Bio- and CO2-based plastics/polymers are being developed. E.g. Covestro is producing polyurethanes commercially, that have a content of 20% captured CO2. So a vision seems to be there already but it has a lot of room for improvement and expansion.	Unclear comment	Jasmin Kemper	IEA Greenhouse Gas R&D Programme (IEAGHG)	United Kingdom (of Great Britain and Northern Ireland)
18503	4	32	4	33	page 4 line 4, the term materials industry. here, the term energy intensive industry. they should be the same? where others like machinery and electronics are manufaturing?	Accepted. Would be clarified.	Jiahua Pan	Chinese Academy of Social Science	China

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
45389	4	32	4	39	It should also be mentioned that this will need revision of existing policy frameworks.	Accepted.	Shareq Mohd Nazir	KTH Royal Institute of Technology	Sweden
13239	4	34	4	34	though there are many promissing breakthrough tehcnologies for steel, most of them ar still in development phase and cannot be decsribed as available	Rejected. Technical readiness for scaling some of them differ, but many technologies are available. Stamens on technological availability will be added if SOD.	Asa Ekdahl	world steel association	Belgium
20527	4	40	4	46	CCU/PtX is not mentioned in this section, but crucial also for industrial processes, in particular for the chemical industry - and CCU/PtX is linked to very low-cost (renewable) electricity	Now in 11.3.6 with extensive teratment of CCU and "power-to..."	Christian Breyer	LUT University	Finland
25217	4	45	4	45	Delete "As a result, effective mitigation options … may be overestimated."	Accepted. Will consider better language in the SOD	Eleni Kaditi	Organization of the Petroleum Exporting Countries (OPEC)	Austria
33003	4	45	4	46	The costs of material efficiency strategies are also highly uncertain and difficult to characterise.	Accepted. Will consider better language in the SOD	Peter Levi	International Energy Agency	France
38983	4	45	4	46	This statement states the obvious underrepresentation of several mitigation options in climate change scenarios. This is mainly due to the fact that IAM's are not able to take specific technologies into account, because of their lack of granularity (as discussed in Annex C) But this teechnical issue should not prevent to discuss in depth these specific mitigations options. For example CCU technologies represent a very fast growing sector that can playa crucial role in decreasing GHG emissions, in the transport, building, energy and industrial sector, but this key concept is absolutely not covered in this report.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 (e.g. Bruhn et al., 2016, Daggash et al., 2018). (Detz and Zwaan, 2019, Energy Policy, 133, 110938./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./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./Bruhn et al., 2016, Environmental Science & Policy, 60, 38–43./Daggash et al., 2018, Sustainable Energy Fuels, 2, 1153-1169./GCI, 2016: Global Roadmap Study of CO2U Technologies, LUX Research & Global CO2 Initiative/IEAGHG, 2019b: Exploring Clean Energy Pathways: the role of energy storage, International Energy Agency./Hepburn et al., 2019: The technological and economic prospects for CO2 utilization and removal, 575, 87-97)	Accepted. CCUS options will be presented in the SOD	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
3255	4	1	6	23	Congratulations to the very well structured and clear executive summary. The basic structure/narrative, e.g. the progress having in mind carbon neutrality as well as the linkage to the relevant SDGs, is highly recommended also for other chapters, such as building, cities or transport.	Thank you.	Klaus Radunsky	retired from Umweltbundesamt	Austria
3259	4	1	6	23	It is strongly recommended to include the precise reference to the main body of the text in order to trace the findings included in the Executive Summary.	It could be done in case such decision is taken for the whole report.	Klaus Radunsky	retired from Umweltbundesamt	Austria
11371	4	1	6	23	Problems and concerns in developing countries for adoption of very low to zero emission technological options have not been properly highlighted in summary chapter. Alteration of technological options towards low and zero emission scenario needs investments and people's trust. Those attempts should not affect product cost, employment scenario, economic balance of the country. CCUS for small and medium scale industry may not be a viable or feasible option when fossil fuels are in use as cheapest option. Increasing use of electricity in fossil fuel may be an option if large scale electricity production be integrated with CCUS. Increasing electricity production and the adoption of CCUS technologies have both positive and negative implications for economic growth and sustainable development. Question of adoption of BAT is really a critical issue particularly in developing countries. Decision is policy driven and emerges after overcoming a socio economic barrier. In view of the constraints, hurdles, cost parameter, socio economic barrier, etc., the confidence level of bulleted statements as mentioned under the parenthesis may be rechecked and revised or modified if possible.	Accepted. Clarification would be added.	PINAKI SARKAR	CSIR-CENTRAL INSTITUTE OF MINING AND FUEL RESEARCH	India
20479	4	1	6	23	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. This is well established term and fits for Ex. Summary and figure below. More distinction between CCS and CCU may be given attention is chapter sections, where they are discussed.	Christian Breyer	LUT University	Finland
45397	4	1	6	23	The impact of digitalisation in industry needs to be discussed as it might also help in mitigating emissions from industrial sector	Accepted.	Shareq Mohd Nazir	KTH Royal Institute of Technology	Sweden
3187	4	2	6	23	Please indicate the Section(s) referenced for each of the paragraphs.	It could be done in case such decision is taken for the whole report.	Sai Ming LEE	Hong Kong Observatory	China
44387	4	9			"carbon capture and use and storage" should rather be"carbon capture, utilization and storage"	Will calibrate the language	Pietro Guarato	University of Lausanne	Switzerland

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33005	5	1	5	5	Important to note the current difficulty/uncertainty associated with running many processes for bulk material production on a variable basis, and/or the significant costs of electricity/hydrogen storage.	Accepted. Would ve considered along with possibitily to store products versus storing energy	Peter Levi	International Energy Agency	France
3183	5	2	5	3	Re: "Electricity is a versatile and carbon free energy carrier". The statement may not be entirely true if the electricity is generated based on fossil fuel combustion. Please consider revision.	Rejected. This highly logical and obivous point was made by several reviewers. We need to deal with it once in a sensible place.	Sai Ming LEE	Hong Kong Observatory	China
40249	5	2	5	3	would revisit calling electricity a carbon free carrier as this does not convey embedded carbon from the generation process	Rejected. This highly logical and obivous point was made by several reviewers. We need to deal with it once in a sensible place.	Vida Rozite	International Energy Agency	France
25219	5	2	5	4	Delete "Electricity is a versatile … low carbon options."	Possible change: "Electricity is a versatile and carbon free energy carrier, potentially produced from very large potential renewable energy sources (e.g., wind, solar), hydropower, or other low carbon options like nuclear and fossil fuels with high percentage capture CCS."	Eleni Kaditi	Organization of the Petroleum Exporting Countries (OPEC)	Austria
40251	5	3	5	3	suggest removing "potential"- repetetive	Accepted. Will calibrate the language	Vida Rozite	International Energy Agency	France
38985	5	6	5	11	Here te role of captured CO2 as potential feedstock and the principe of CO2 circular economy should also be discussed.CCU plays a key role there: In the industrial sector, 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 /Bruhn et al., 2016, Environmental Science & Policy, 60, 38–43./Sustainable Energy Fuels, 2, 1153-1169/Koytsoumpa et al., 2018, The Journal of Supercritical Fluids, 132,3–16)	Accepted. Is considered in the chapter under CCU which is mostrly used as feedstock.	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
13241	5	9	5	9	Direct air capture seems a long way off to being commercialy available. BECCS makes much more sense considering the much higher CO2 content of the gases	"Potentially" added to signal this	Asa Ekdahl	world steel association	Belgium
15681	5	9	5	9	You mention that in the context of net zero emissions, the carbon used in products could come from "biomass feedstock or direct air capture," but you don't mention that carbon could be captured from exhaust streams, where it is available at higher concentrations (and is easier to separate) than from the atmosphere. Even in a world with "net zero" emissions, there still will be some exhaust streams that could be sources of CO2 that can be captured more easily than extracting CO2 from the atmosphere with direct air capture. Maybe it's worth including this option as well, as a potential source of carbon.	Accepted.	Jeffrey Rissman	Energy Innovation: Policy and Technology LLC	United States of America
44817	5	10	5	10	CDR technologies should be explained, illustrated	Rejected. The summary is not the placece for both expanation and illustration. They will be givcen in body text.	Véronique Waroux	Planète-A	Belgium
3185	5	10	5	11	Re: "Carbon dioxide removal (CDR) technologies can be used to balance net emissions where recirculation is difficult". CDR technologies are not mature yet and large-scale deployments are subject to a number of constraints. See line 31-33, page 60 of Chapter 3: "CDR ramp-up rates and absolute deployment levels are tightly limited by techno-economic, political and sustainability constraints". Also see line 27-42, page 7 of Chapter 4 of the Special Report on Global Warming of 1.5oC: "Most CDR options face multiple feasibility constraints". Please consider revision of the statement to avoid painting an overly optimistic picture.	Accepted	Sai Ming LEE	Hong Kong Observatory	China
3257	5	10	5	11	The notion, to compensate residual GHG emissions by CDR (carbon dioxide removal) should also become element of other sectors/chapters. Furthermore it would be quite helpful a) to give some indication of the overall amount of CDR required and b) to identify which approaches/technoloogies could deliver at the required scale and at what current costs.	Agree, see other chapters	Klaus Radunsky	retired from Umweltbundesamt	Austria
40253	5	12	5	13	lacks justification for why costs would be low for final consumers and the general economy - costs will be passed on to consumers and there may be implications for the economy	Rejected. Justification is given in the body text with the references on literature.	Vida Rozite	International Energy Agency	France
32113	5	12	5	20	There are different levels of emissions reduction potential: technological, economic, and social, etc. Technological potentials do not necessarily guarantee mitigation. This point needs to clarified in the summary and the underlying main chapter text.	Accepted. Would be clarified that chapter mainly speaks on technological potential with some costs tags and consider barriers which limit the potential realization.	Masahiro Sugiyama	University of Tokyo	Japan
33007	5	12	5	20	20%-40% cost premium for innovative routes for low CO2 steel production seems at the low end of the range.	To be substantiated. This would be for the nth plant with current elec prices.	Peter Levi	International Energy Agency	France
11375	5	17	5	17	'Directs costs' would be 'Direct costs'	Thank you	PINAKI SARKAR	CSIR-CENTRAL INSTITUTE OF MINING AND FUEL RESEARCH	India
40255	5	19	5	20	some reference to methodology used here would be helpful	Rejected. References are given int the body text	Vida Rozite	International Energy Agency	France
13243	5	20	5	20	the cost estimates for making low carbon steel seems low. HYBRIT in Sweden estimates 30% increased cost and they have all the best pre-conditions. We believe that for most steel makers it is likely to be much higher, up to 100%	Accepted. Costs ranges will be updated in the SOD based on literature	Asa Ekdahl	world steel association	Belgium
40259	5	21	5	38	could consider including reference to use of alternative low-carbon materials	Accepted.	Vida Rozite	International Energy Agency	France
34459	5	23	5	23	"steel demand reduced by up to 40%". Is it global demand or primary steel demand ? This needs to be precised.	Accepted. Clarification will be added.	Emmanuel RAUZIER	NGO Association negaWatt	France
13245	5	26	5	28	There are a number of projects injecting H2 into the Blast Furnace (BF) but the possibilities are limited due to the need for coke to keep the internal structure and permeability of the reducing materials	Thank you	Asa Ekdahl	world steel association	Belgium

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
38987	5	27	5	28	Please rephrase: Production decarbonisation will also be required, starting with the retrofitting of existing facilities for partial fuel switching (e.g.to hydrogen, CO2 based synthetic fuels), followed by very low and zero emissions production based on CCU or direct hydrogen or electrolytic iron ore reduction followed by an electric arc furnace.)	Accepted.	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
3261	5	29	5	29	There are several …. (insert: are)	Thank you	Klaus Radunsky	retired from Umweltbundesamt	Austria
11373	5	29	5	29	‘there several’ would be there are several	Thank you	PINAKI SARKAR	CSIR-CENTRAL INSTITUTE OF MINING AND FUEL RESEARCH	India
11829	5	29	5	29	Please inlude "are" in this sentence. Should be "There are several…"	Thank you	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
45391	5	29	5	38	It is worthwhile also mentioning about the changes in the equipment that needs to be made while fuel-switching or potentially using electricity and hydrogen.	Agreed, but in the full text and not the summary	Shareq Mohd Nazir	KTH Royal Institute of Technology	Sweden
11831	5	31	5	32	Clarify what is currently overused (cement and concrete). Is it possible to expand some more on to what extent concrete is being overused?	Accepted.	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
2215	5	32	5	32	It should be "concrete" instead of "cement".	Accepted.	Miguel Angel Sanjuán	Technical University of Madrid	Spain
12535	5	32	5	32	It should be "concrete" instead of "cement".	Accepted.	MORA PERIS PEDRO	Profesor Titular de Universidad de la ETSI Minas y Energía de la Universidad Politécnica de Madrid	Spain
40257	5	32	5	32	suggest checking terminology "well-made cement"	Thank you. Will consider for editing	Vida Rozite	International Energy Agency	France
2219	5	33	5	33	Add after "…aggregates…": "...adequate cement selection and concrete mix design to optimise carbon uptake and enhance durability)".	Thank you. Will consider for editing	Miguel Angel Sanjuán	Technical University of Madrid	Spain
12539	5	33	5	33	Add after "…aggregates…": "...adequate cement selection and concrete mix design to optimise carbon uptake and enhance durability)".	Thank you. Will consider for editing	MORA PERIS PEDRO	Profesor Titular de Universidad de la ETSI Minas y Energía de la Universidad Politécnica de Madrid	Spain
34225	5	33	5	33	It is said that 'emissions' could be reduced by 24-50% , but the whole paragraph doesn't explain what emissions we are speaking of [suggestion ENSEEIHT INP]	Accepted. Clarification would be provided	Antoine BONDUELLE	Climate Action Network France	France
44819	5	34	5	35	We are not talking about carbonation of limestone for the production of cement, but rather about decarbonation, a process of transformation of calcium carbonate.	Accepted. Clarification would be provided	Véronique Waroux	Planète-A	Belgium
14281	5	34	5	38	Addition: "For steel, cement & concrete production and other energy intensive industries, mineral carbonation offers a solution to utilise CO2 from industrial emissions, treat industrial waste fractions (like steel slag, construction and demolition waste, fly ash, cement kiln dust, etc.) and produce novel construction materials (CO2-based concrete, CO2-based aggregates, CO2 concrete curing, etc.). Also natural minerals (olivine, serpentine) can serve as input material for minera lcarbonation (di Maria et al., 2020, https://doi.org/10.1016/j.ijggc.2019.102882; Andrade et al., 2018, https://doi.org/10.1016/j.conbuildmat.2017.11.089; Kirchoffer et al., https://doi.org/10.1016/j.egypro.2013.06.510; Giannoulakis et al., 2014, http://dx.doi.org/10.1016/j.ijggc.2013.12.002; Bobicki et al., 2012, https://doi.org/10.1016/j.pecs.2011.11.002; Nduagu et al. 2013, http://dx.doi.org/10.1016/j.apenergy.2013.01.049, Bodenan et al., 2014, http://dx.doi.org/10.1016/j.mineng.2014.01.011)"	Thank you. Will consider for editing	Anastasios Perimenis	CO2 Value Europe (Association) - CCU Offiver	Belgium
2217	5	35	5	35	It should be "calcination" instead of "carbonation".	Thank you. Will consider for editing	Miguel Angel Sanjuán	Technical University of Madrid	Spain
5727	5	35	5	35	Ouch! It is the CALCINATION process you are talking about. Carbonation is the reverse reaction.	Thank you. Will consider for editing	paul fennell	Imperial College	United Kingdom (of Great Britain and Northern Ireland)
12537	5	35	5	35	It should be "calcination" instead of "carbonation".	Thank you. Will consider for editing	MORA PERIS PEDRO	Profesor Titular de Universidad de la ETSI Minas y Energía de la Universidad Politécnica de Madrid	Spain
44821	5	36	5	36	Electrification of cement kilns: Are there any examples?	No, but it has be worked on at the lab level.	Véronique Waroux	Planète-A	Belgium
5729	5	37	5	37	Eliminating cement emissions WITH new chemistries will likely take decades etc. You can just use post combustion CCS and make standard ordinary portland cement. Or you could do e.g. oxyfuel or leilac and you haven't changed the underlying chemistry. NEW cements will require decades.	Agreed.	paul fennell	Imperial College	United Kingdom (of Great Britain and Northern Ireland)
15683	5	39	5	40	The opening sentence of this paragraph is not entirely clear that we're talking about decarbonizing the chemical manufacturing industry. When you say, "decarbonizing the main feedstock chemicals and their derivatives," some readers might misinterpret this to mean finding low-carbon substitutes for these chemicals, rather than making the usual chemicals, but in a low-carbon way. Adding a few words should help clarify, like this: "decarbonizing the production of the main feedstock chemicals and their derivatives"	Accepted. Clarification would be provided	Jeffrey Rissman	Energy Innovation: Policy and Technology LLC	United States of America

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
36371	5	39	5	47	Chemical industry is a good example that the emissions are significant in the industry but marginal emission reduction potentials in other sectors which use chemical products or use parts and supplies made of chemicals far exceeds marginal emission increase in the chemical industry. The contribution of an industry sector to other sectors in the emission reductions need to be disussed in the chapter. Such discussion is unfortunately very poor in this draft. https://www.icca-chem.org/energy-climate/	I disagree with this reviewer. This is lobbying speak from the chemical industry, that "their" emissions enable other emissions reduction.	Shigetaka Seki	Consumer Product Safery Association	Japan
40261	5	39	5	47	lacks information on what are the decarbonisation options	Accepted. Clarification would be provided	Vida Rozite	International Energy Agency	France
15685	5	44	5	47	The last sentence of this paragraph could use some copy editing.	Accepted. Clarification would be provided	Jeffrey Rissman	Energy Innovation: Policy and Technology LLC	United States of America
38989	5	44	5	47	Captured CO2 should also be considered as major carbon feedstock for the industry. 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). (Zhu, 2019, Clean Energy, Vol. 3, No. 2, 85–100./Hepburn et al., 2019: The technological and economic prospects for CO2 utilization and removal, 575, 87-97.)	Accepted.	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
11833	5	46	5	46	Please inlude "a" in this sentence. Should be "..in a low carbon world…"	Thank you.	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
14283	5	47	5	47	Addition: "Next to biomass and recycled plastic, CO2 from industrial emissions or directly from the atmosphere is the only remaining alternative carbon source and can lead to emission reductions in the chemical industry (Thonemann 2020, https://doi.org/10.1016/j.apenergy.2020.114599; Valderama et al. 2019, https://doi.org/10.1016/j.eurpolymj.2019.07.036; Kätelhön et al. 2018, https://doi.org/10.1073/pnas.1821029116; IEA 2019, https://www.iea.org/reports/putting-co2-to-use)"	Accepted. Clarification would be provided	Anastasios Perimenis	CO2 Value Europe (Association) - CCU Offiver	Belgium
10611	5	5	#REF!	3	"Electricity is a versatile and carbon free energy carrier…" Perhaps add "potentially" after "is". At present, electricity is not really carbon-free.	Thank you.	David Schoeman	University of the Sunshine Coast	Australia
44389	5	29			typo: "There several current" should be "There are several current"	Thank you.	Pietro Guarato	University of Lausanne	Switzerland
44391	5	31			"It is currently overused" should better be written "Cement is currently overused", to avoid possible ambiguities.	Accepted.	Pietro Guarato	University of Lausanne	Switzerland
14285	6	1	6	3	Addition: "heat pumps, waste heat use, CO2-based fuels and hydrogen"	Thank you. Will consider for editing	Anastasios Perimenis	CO2 Value Europe (Association) - CCU Offiver	Belgium
13247	6	4	6	5	Provided that the biomass is sustainably sources	Thank you. Will consider for editing	Asa Ekdahl	world steel association	Belgium
13249	6	6	6	6	They are not a large NET emitter due to biomass input but if they reduced or used CCS they have the potential to go negative!	Thank you. Will consider for editing	Asa Ekdahl	world steel association	Belgium
40263	6	7	6	8	lacks word depicting what trend for building materials and petrochemical will drive competition	Thank you. Will consider for editing	Vida Rozite	International Energy Agency	France
40265	6	9	6	10	relevance and value add of this statement is not clear	Thank you. Will consider for editing	Vida Rozite	International Energy Agency	France
15687	6	16	6	17	This sentence mentions two of the main reasons industry has thus far been sheltered from climate policy impacts: concerns for competitiveness and carbon leakage. This is correct. But I believe a third reason is that industry has often been seen as too complicated and heterogenous to regulate effectively by government experts, who don't know the specifics of the manufacturing processes for every different type of goods. (This can be overcome through smart policy design, such as using price incentives and technology-neutral standards that do not require the government to know the technical details of how to run every type of manufacturing business.) Companies sometimes claim that government doesn't understand their technology or their business as a strategy to fighting against government regulation (e.g. to give the public the impression that government is unqualified to regulate their industry, and thereby undermine public support for regulation). Do you think it's worth mentioning this reason as well, and later in the same paragraph, that it can be addressed through smart policy design?	Accepted.	Jeffrey Rissman	Energy Innovation: Policy and Technology LLC	United States of America
9755	6	16	6	23	Korea industrial policy also recognizes and reflects strengthening environmental regulations as one of the major mega-trends, thus many of strategies are related to eco-friendly manufacturing and green industries is targeted as new growth engine. However, in countries where manufacturing is a major base, such as Korea, the environmental/climate policies of rival countries can affect the competitiveness of their industries. Thus, efforts should be made at the international level to make individual countries having comparable degree of environmental regulation.	Thank you.	JAE YOON LEE	Korea Institute for Industrial Economics and Trade(KIET)	Republic of Korea
2619	6	24	6	24	In addition to the topics discussed in the preceeding sections, 3 industries emit long-lived high-GWP PFC gases like CF4 and C2F6, namely semiconductor, aluminium and rare earth manufacturing. In the case of semiconductors, PFCs are used as process gases for etching and their emissions have been reduced by >90% since the 1990's by pro-active action by the World Semiconductor Council (WSC), by the substitution of less-impactful gases and the widespread implementation of exhaust gas abatement equipment to destroy these gases at the point of use. In the case of aluminium, the International Aluminium Institute (IAI) has promoted adoption of technologies to minimise the occurrance of anode events which are the primary source of emissions. Rare earth manufacture is at an early state of development but is likely to become a dominant source of PFC emission with Nd being a key component of high-power magnets used in wind turbing generators and the motors in electric vehicles.	Thank you.	Michael Czerniak	Atlas Copco - Edwards	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
38405	7	6	7	7	I recommend rewording this sentence to say "This chapter takes its starting point in this new context and emphasizes the need to enhance efforts to improve energy and process efficiency while also increasing efforts to realize other emissions reduction options in order to limit warming to 1.5 ºC or 2ºC (IPCC 2018)." There is no reason to "go beyond" energy and process efficiency before they are fully exploited (which they certainly aren't in most sectors in most countries), especially since these often represent the most cost-effective options.	Thank you. Will consider for editing	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
38593	7	6	7	7	You cite the IPCC's 1.5 Degree report (IPCC 2018) for this statement, but I note that this report says: "Broadly speaking, the industry sector's mitigation measures can be categorized in terms of the following five strategies: (i) reducing demand, (ii) energy efficiency, (iii) increasing electrification of energy demand, (iv) reducing the carbon content of non-electric fuels, and (v) deploying innovative processes and application of CCS. IEA ETP estimates the relative contribution of different measures for CO2 emission reduction in their B2DS scenario compared with their reference scenario in 2050 as follows: energy efficiency 42%, innovative process and CCS 37%, switching to low-carbon fuels and feedstocks 13% and material efficiency (include efficient production and use to contribute to demand reduction) 8%." I suggest that you reword this opening statement to something like"This chapter takes its starting point in this new context and emphasizes the need to enhance efforts to improve energy and process efficiency while also increasing efforts to realize other emissions reduction options in order to limit warming to 1.5 ºC or 2ºC (IPCC 2018)." There is no reason to "go beyond" energy and process efficiency before they are fully exploited (which they certainly aren't in most sectors in most countries), especially since these often represent the most cost-effective options.	Accepted. More sources would be added.	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
34241	7	8	7	9	[suggestion ENSEEIHT INP]Missing numbers in the percentages (X and Y)	Will be added in the SOD	Antoine BONDUELLE	Climate Action Network France	France
40221	7	8	7	9	X% and Y% should be replaced by a number each	Will be added in the SOD	Ana Ines Fernandez	University of Barcelona	Spain
40267	7	8	7	9	values missing - partly available on https://www.iea.org/reports/tracking-industry	Will be added in the SOD	Vida Rozite	International Energy Agency	France
18803	7	9	7	9	"total direct and indirect industrial emissions"- incuding process emissions. Not only energy-related emissions.	Accepted. Clarification would be provided	Andreas Schroeder	International Energy Agency IEA	France
38407	7	11	7	12	Your mandate is to review the current literature, not to defer to the coverage of a topic in the previous Assessment Report. If energy efficiency "remains a key mitigation option and is important even as final energy use in industry becomes less emissions intensive", then it should be included and covered to the degree of its importance in this chapter. I see that you do cover energy efficiency on pages 23-25.	Rejected. The energy efficiency was better covered in previous reports comparing with other new mitigations options, which are expected to provide at least equal contribution by the mid century. So those new options deserve more attention in the chapter next to energy efficiency.	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
38409	7	23	7	25	I really don't understand much of this equation. The Kaya Identity is basically GHG emissions = activity drivers (you have population) x economic drivers (you have GDP/population) x energy intensity (you have E/MPR+MSE) x GHG intensity (you have GHGed + GHGeind/E). This all makes sense to me. What is confusing is that you also have Mstock/GDP x MPR+MSE/Mstock which cancels out to be MPR+MSE/GDP - what is this? It seems to be industrial material production over GDP. Are you using this as an activity driver instead of population? If so, why is it over GDP? I am also confused by the second half of the equation - I think it is the placement of the last parenthesis and the addition of the GHGoth/MPR+MSE.	Rejected. This identity introduces among others several new drivers comparative ro regulare ones. Materials use is split by primary and secondary material production. This important as circular economic allows to reduce the share of more energy intensive primary materials production. GHG emissions are split by three components (direct, indirect and processes related for which drivers are different. Population and GDP are in the identiry. So new drivers are used not to replace but to supplement those. All parenthesis are at appropriate places. Edgar Hertwich in his comments below conciders such modification very useful.	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
2621	7	24	7	24	Given my comment 35 above, equation11.4 on line 24 does not adequately describe emissions from semiconductor manufacture since it is unconnected to terms MPR + MSE.	Rejected. There is another component in the identity - GHGoth which reflects industrial processes related emissions.	Michael Czerniak	Atlas Copco - Edwards	United Kingdom (of Great Britain and Northern Ireland)
34227	7	30	7	33	The definition of the 'share of allocated emissions Dm' is confusing and could be better explained [suggestion ENSEEIHT INP]	Rejected. There is a clarification given in brakets, which explain how Dm is set in the identity.	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
22955	7	18	8	11	This section provides a very appropriate framing of emissions reducitons around the stocks and flows of materials. This has the advantage of pointing to the dynamics of industrial production and the build-up of machinery and infrastructure to generate the GDP. At the same time, the operational emissions are neglected. However, not all emissions are connected to the build-up of stocks. There are also emissions that are connected to the operation of the stock, as well as emissions related to the production of short-lived products that do not enter the stock. For the materials-related emissions, stock formation and replacement today is more important than operations (about 2/3 of material-related emissions are from capital formation), but for emissions from manufacturing processes and services, this is not the case. These issues can be analysed using MRIO datasets. See https://osf.io/n9ecw (doi 10.31235/osf.io/n9ecw). These methods can be extended for a wider analysis which would be applicable here.	Rejected. Thank you for nice words on framing. Operational emission is, of course, included as E in given decriptio includes energy to transform, refine and assemble industrial products (all operational energy use is included in one of those), not only energy to produce materials.	Edgar Hertwich	Norwegian University of Science and Technology	Norway
37049	7	3	29	44	The chapter can benefit from the new publication forthcoming. a.Rissman,Jeffrey Chris Bataille, Eric Masanet, Nate Aden, William R. Morrow III, Nan Zhou, Neal Elliott, Rebecca Dell, Niko Heeren, Brigitta Huckestein, Joe Cresko, Sabbie A. Miller, Joyashree Roy, Paul Fennell, Betty Cremmins, Thomas Koch Blank, David Hone, Ellen D. Williams, Stephane de la Rue du Can, Bill Sisson, Mike Williams, John Katzenberger, Dallas Burtraw, Girish Sethi, He Ping, David Danielson, Hongyou Lu, Tom Lorber, Jens Dinkel, Jonas He, (2020), Technologies and policies to decarbonize global industry: review and assessment of mitigation drivers through 2070, Applied Energy, (accepted for publication, forthcoming). Also in grey litearture category https://iea-industry.org/publications/report-deep-decarbonization-in-industry/	Accepted. Thank you. We will be happy to use this paper after it is publiched.	Joyashree Roy	Asian Institute of Technology, Thailand. Jadavpur University, India	Thailand
11835	8	3	8	3	Please inlude "the" in this sentence and rearrange. Should be "..when the three last multipliers…"	Accepted. Thank you	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
34229	8	3	8	3	Maybe instead of 'the three last multipliers in the identity', it could be clearer to mention the terms. [suggestion ENSEEIHT INP]	Rejected. Listing back names on several parameters, which were presented in full just a few lines above would make text less user friendly.	Antoine BONDUELLE	Climate Action Network France	France
38411	8	6	8	8	The graphic shows that energy efficiency dominates in the short, medium, and long term, while other options contribute more in the longer term. I suggest that the sentence coud read: "For deep decarbonisation trajectories, energy efficiency dominates in the short, medium, and long term, but contributions from other drivers steadily grow as the share of non-energy sources in industrial emissions escalates and emerging technologies to address those sources mature."	Accepted, We will revise this text to make this clear.	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
11837	8	10	8	10	The abbrivations are not easy to understand. Seems the colors of the graph and the explanations are not matching.	Accepted.	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
8917	8	11	8	11	It is difficult to relate the table to the figure. Removing abbreviations and having clear descriptions of in the graph would help. Matching colors in the table and graph would also make it clearer.	Accepted. We will harmonize color coding on the figure and assosiated table.	Johannes Morfeldt	Chalmers University of Technology	Sweden
36783	8	11	8	11	despite the figure is only illustrative, a x-axis would be required	Accepted. We will harmonize color coding on the figure and assosiated table.	Vincenzo Spallina	University of Manchester	United Kingdom (of Great Britain and Northern Ireland)
22957	8	15	12	28	This section is well researched, citing very relevant publications, and provides a good framing. On my notes, I have several 'good!' exclamations, because the framing is cutting edge and provides a novel and useful perspective compared to previous reports. At the same time, the section is not entirely there yet and requires more work on the details and some better referencing. What I miss is the connection to other chapters. Demand drivers are taken up both here and in the subsequent section. Whereas 11.2.2 has an analysis of traditional production-based emissions, this analysis suggests but fails to provide a consumption-based accounting of emissions. For example, a significant portion of materials is turned into structures (ca. 40% in terms of embodied emissions of materials), machinery and equipment (ca. 20%) and vehicles/transport equipment (ca. 10-15%), see https://osf.io/n9ecw. At the same time, from a consumption perspective, when capital is endogenized, final demand for output of the industry sector is still the most important driver of emissions, accounting for 50% of the total carbon footprint. Within the industry sector, services (apart from building and transport services, which are allocated to the respective sectors) account for nearly 30 percentage points of global CO2 emissions. I think these aspects are important and would add to the analysis provided here. See https://doi.org/10.1088/1748-9326/aae19a	Accepted. We will improve this text along suggested lines with hope that the project Edgar Hertwich and his colleagues are working on right now would end-up with some papers to relay upon.	Edgar Hertwich	Norwegian University of Science and Technology	Norway
20691	8	3			Word "identity" needs to be modified to "Equation".	Rejected. It is modification of Kaya identity.	JUNGYU PARK	International Energy Agency	France
44393	8	3			typo: "when three last multipliers" should be "when the three last multipliers"	Accepted.	Pietro Guarato	University of Lausanne	Switzerland
20693	8	10			Having column name would be helpful to understand table easily.	Accepted. We will provide columns' names	JUNGYU PARK	International Energy Agency	France
8919	9	1	9	4	Confusing sentence. How does emissions from industrial processes and waste inhibit emissions growth?	Accepted. Will make the statement more clear	Johannes Morfeldt	Chalmers University of Technology	Sweden
38413	9	1	9	4	This is a confusing sentence. Perhaps a re-write could be "Key driving factors behind the evolution of industrial GHG emissions since 1900 are both on the growth side (population and per capita GDP) and the reduction side (energy efficiency and emissions intensity). I'm not sure about this: "GHG emissions from both industrial processes and waste per unit of extracted materials inhibited emissions growth." How do these inhibit emissions growth?	Accepted. Will make the statement more clear	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
44395	9	1	9	4	Very confused (and sometime grammatically incorrect) sentence!!	Accepted. Will make the statement more clear	Pietro Guarato	University of Lausanne	Switzerland
34231	9	2	9	3	What is the meaning of : 'factors that reduce emissions are energy efficiency and GHG emissions' ? [suggestion ENSEEIHT INP]	Accepted. Will make the statement more clear	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
12971	9	2	9	4	sentence awkward and confusing, particularly as it relates to factors putting downward pressure on emissions	Accepted. Will make the statement more clear	Robin White	Environment & Climate Change Canada, Government of Canada	Canada
12973	9	5	9	5	meaning unclear for the phrase: "...were cyclically switching their contributions…"	Accepted. Will make the statement more clear	Robin White	Environment & Climate Change Canada, Government of Canada	Canada
22959	9	8	9	15	Here, the authors present an analysis they conduct based on various sources and the equation presented in section 11.1.2. See my comment on that section. The equation is incomplete, as it does not provide a complete accounting for emissions, which are not all related to the stock. A decomposition analysis of total emissions from the industrial sector is hence meaningless as the equation that is being used to decompose these emissions is incomplete. The work here has not been peer-reviewed, and no data or method description is provided. Also, all the usual weaknesses of index decomposition apply, such as information loss in aggregating things to a global level, lack of unique decomposition but depence on the exact decomposition approach (which is not specified), and implicit but unjustifiable assumption of unit elasticity. I would reconsider this presentation both because it is scientifically problematic and because it does not offer so much insight.	Rejected. There is no place in this para, where notion of decomposition is mentioned. The figure only presents annual growth rates of different drivers mentioned in the identity with clear references on sources of statistical data. Such clarification will be given in the figure caption. The IPCC task is not to copy paste what is written in the literature, but make assessments, including compiling data from different sources. As to the completeness of the Identity 11.1, the replay on comment for not including operating energy use and assosiated GHG emissions is already provided above. So it is perfectly complete.	Edgar Hertwich	Norwegian University of Science and Technology	Norway
11839	9	9	9	9	What is "AAGR"? I pressume it's something to do with average annual growth, but could be written out. Otherwise an informative graph.	Accepted.	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
38415	9	9	9	9	Please also provide the data for material production (MPR+MSE in your formula) as this is a key driver of GHG emissions.	Accepted	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
38417	9	9	9	9	One of the most notable things about this figure is the energy/materials data showing that energy use per materials produced (as an indicator of energy intensity or energy efficiency) grew more slowly than the other drivers. I recommend that you include a discussion of this, noting how this helps to offset the growth in other drivers.	Accepted	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
22961	9	16	10	15	I like the first paragraph very well. I also think the information provided in the second paragraph is quite valuable.	Accepted. Thank you. This addresses the issue was rised by Edgar above.	Edgar Hertwich	Norwegian University of Science and Technology	Norway
20695	9	9			Please consider that Industrial energy use is available from IEA World Energy Balances (http://data.iea.org/payment/products/117-world-energy-balances.aspx), while CO2 Emissions from Fuel Combustion are available from the IEA (http://data.iea.org/payment/products/115-co2-emissions-from-fuel-combustion.aspx).	Accepted, The IEA is listed abong sources.	JUNGYU PARK	International Energy Agency	France
18505	10	3	10	4	the information showing her "In 1900–2018, the stock thus escalated 30-fold, which is nearly as fast as GDP growth (37 fold). While the composition of basic materials in the stock of manufactured capital" indicates that urbanization is a driver, probably a key driver. Therefore, locked in and low carbon urban infrastructure important for industries.	Accepted	Jiahua Pan	Chinese Academy of Social Science	China
34233	10	9	10	9	Figure 11.2 : The acronym 'AAGR' in the table is not defined [suggestion ENSEEIHT INP]	Accepted. Change for global GDP energy intensity	Antoine BONDUELLE	Climate Action Network France	France
34235	10	11	10	11	It could be relevant to define 'global energy intensity' in particular with regard to which agregates and sources are used in the long run (1900). [suggestion ENSEEIHT INP]	Accepted. Change for global GDP energy intensity	Antoine BONDUELLE	Climate Action Network France	France
22963	10	21	10	25	This needs to be much better explained. In a dynamic stock-flow context, the main mechanism by which the role of recycled materials can increase is for the growth rate to slow down, so that the previously produced stock which becomes available for secondary materials production is larger compared to the current level of demand.	Accepted. Clarification will be added with the reservation that very detailed description conflicts the chapter size limits as many other issues are to be covered.	Edgar Hertwich	Norwegian University of Science and Technology	Norway
22965	10	30	11	1	There is a potential confusion in the terminology. Please clearly refer to recycling input ration and EoL-recycling ratio as defined in the literature, for example by Graedel et al.	Accepted. Terminology will be checked for full compliance with the references provided in the section.	Edgar Hertwich	Norwegian University of Science and Technology	Norway
13251	11	1	11	3	This ios not a good metric when production is growing (substanitally). The denominator (steel demand) has grown a lot more than the nominator (scrap availability). If the life time of steel products (already at 30 years) increases due to circular economy policies the scrap availability will grow slower in the future	Accepted. Clarification will be added on demand growth.	Asa Ekdahl	world steel association	Belgium
22967	11	1	11	7	Be clear whether you are using percentages or percentage points. I cannot understand those numbers. Maybe the data would be better presented in a Table? Please note that there is a potential overlap with the discussion on the Circular Economy in Chapter 5.	Rejected. Text in this para says from % to % with no statement is made in form of by %. So, it is clear that percents not percent points are presented.	Edgar Hertwich	Norwegian University of Science and Technology	Norway
18799	11	3	11	3	Interesting to see that scrap use in steel went down. Al this in spite of talk of electrification of steel and more secondary produciton.	Thank you. No reaction is needed	Andreas Schroeder	International Energy Agency IEA	France
8835	11	6	11	6	I suggest this sentence is clarified and elaborated further. Please see the following papers as references: doi.org/10.1126/science.1260352 ; doi.org/10.1126/sciadv.1700782 ; doi.org/10.1016/j.rser.2014.07.114 ; doi.org/10.1057/s41599-018-0212-7	Accepted. We will check this paper. Possible elaboration is limited by the chapter page limit.	Saygın Değer	SHURA Energy Transition Center	Turkey
18801	11	6	11	6	Plastics collection rate only 10% globally, but with huge variations across countries (technology is available)	Accepted.	Andreas Schroeder	International Energy Agency IEA	France

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
33009	11	6	11	6	The IEA and McKinsey currently estimate the collection rate for major plastic resins to be around 15-17% in recent years. It is true that a lot of this material is 'down-cycled', so the overall recycling rate is lower - important to describe exactly what the number refers to.	Thank you. No reaction is needed	Peter Levi	International Energy Agency	France
22969	11	11	11	14	What does this mean? What ratio is this and what does it tell us? Do we really need it?	Rejected. This ratio shows how much more primary materials are to be extracted in relation to already accumulated stock to provide services needed. So it shows whether demand for new capital is more or les basic material intensive.	Edgar Hertwich	Norwegian University of Science and Technology	Norway
22971	11	15	11	24	Can we really make global statements like this based on the analysis referenced here, which is from a single world region. I woud venture that the quantitative analysis of the global emissions trends is very much shaped by the emergence of China as a manufacturing powerhouse. As the analysis by Schandl et al. (10.1111/jiec.12626) shows, global materials intensity of the economy has grown since 2000 while materials intensity of individual countries has declined; this is a result of the disproportionate growth of those regions in the world economy which are comparatively materials-intensive. It is a general problem with conducting analysis at the aggregate. In any case, the statement presented in this paragraph seems to be poorly substantiated.	Accepted. Will look for more references.	Edgar Hertwich	Norwegian University of Science and Technology	Norway
34237	11	15	11	24	This sentence is to long to be well understood [suggestion ENSEEIHT INP]	Thank you revised	Antoine BONDUELLE	Climate Action Network France	France
11841	11	20	11	21	Could the statement that carbon costs are not being passed downstream because of compensation mechanisms be elaborated some more?	Accepted	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
34461	11	21	11	23	"to exploit such options as unusefull products consumption reducing, light weighting......."	Not clear. Add "unuseful" is the request? What is unuseful? Reject	Emmanuel RAUZIER	NGO Association negaWatt	France
33011	11	24	11	26	I would strongly dispute this sentence. What does 'hard to abate' mean then? I would say that heavy industrial sectors are hard to abate for three key reasons: many of the technologies required for deep emissions reductions are at low levels of technology readiness, assets in the sector are long-lived and capital-intensive, and trade complicates the process of taking action on the policy front without co-ordinated efforts across jurisdictions. I would say that heavy industry sectors are among the most deserving of this description among energy sub-sectors, alongside long distance transport.	Thank you. Agree and this is elaborated in other places	Peter Levi	International Energy Agency	France
18865	11	24	11	27	The chapter disagrees with the term of "hard to abate" for industrial sectors. I think it is a strong statements and needs convincingly explanation for whay it is not hard to abate.	Accepted. This comment is related to the whole chapter. Additional efforts will be made to show that there are technologies allowing for net-zero emissions in the industrial sector.	Etem Karakaya	Independent researcher, former Profesor,fired with the decree of law since 2016	Turkey
13253	11	25	11	25	The term "hard to abate" relates to the fact that we are not mearly talking about fuel switching but new production processes and that these will mean significant investments. The steel industry also operates at very low margins and is highly internationally traded which reduces the possibilities to pass on costs to customers	Thank you. No reaction is needed	Asa Ekdahl	world steel association	Belgium
45393	11	34	11	36	Could we specify one or two examples of major policies adopted by China that temporalily levelled off industrial energy use.	Rejected. Here is the section on global trends with no details on policies by countries. Policy examples are to reflected in 11.6.	Shareq Mohd Nazir	KTH Royal Institute of Technology	Sweden
38421	11	38	11	39	What are "aggregated industrial energy efficiency indicators"? Please define. What is meant by "progressing slower"? Please define. The next sentence that starts "They only temporarily" is also unclear - can it be written more clearly? Both of these sentences also need a reference.	Accepted. Will be revised in line with suggestion below.	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
38423	11	39	11	42	Suggested re-write to be clearer: "Between 2000 and 2017, the economic energy intensity (measured as energy use per gross value added in 2016 dollars) of manufacturing industries in major economies dropped by 25% (using PPP) or 6% (using MER) (IEA, 2018; IEA, 2019b; citation for https://www.iea.org/tcep/industry/).	Accepted. Will be revised in line with this suggestion.	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
38425	11	42	11	42	Suggest using "Physical energy intensity" instead of "Phyical indicators" since this is a measure of energy intensity using a physical unit for the denominator vs an economic one as used in the previous sentences in this paragraph.	Accepted. Will be revised in line with this suggestion.	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
40269	11	34	12	1	could revisit in light of reference from 2011	Unclear comment	Vida Rozite	International Energy Agency	France
38419	11	38	12	8	If this paragraph is supposed to describe the energy/materials data presented in Figure 11.2, then it could be improved. First, it is notable that of all of the data presented in Figure 11.2 only energy/materials and GHG emissions (other)/materials growth rates are negative for all time periods. I suggest that this paragraph start with a summary sentence pointing this out as this provides a significant dampening effect to offset the other elements that contribute to emissions growth. Perhaps something like "For all time periods shown in Figure 11.2 (covering 1900-2018) the growth of energy use per materials produced was negative, indicating that energy intensity improvements contributed to reducing GHG emissions offsetting growth in material demand during this time period."	Accepted. Will be revised in line with this suggestion.	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
13695	11	44	12	9	Not sure if this comment is best addressed here or elsewhere in the chapter, but generally more comment could be added on the benefits of adopting building and construction codes (including for off-site manufacturing of building components) that emphasise whole life / cradle to crade costs and impacts (positve and negative) as part of a transition to a circular economy. There are many benefits to be had from designing and constructing buildings from natural, sustainable building materials that are 100% recyclable and / or biodegradable - and this also links with the chapter on land use, land use change and forestry. These include job creation, economic regeneration, and enhancing biodiversity. For some examples frm Scotland and Northern Europe see www.neesonline.org and https://commonweal.scot/policy-library/common-home-plan	Accepted. This suggestion may be reflected in the earlier part of this section.	Keith Baker	Built Environment Asset Management (BEAM) Centre, Glasgow Caledonian 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
36373	11		12		It is true that there is a large potential of recycling which can substantially reduce the emissions, however, it should be noted that there are limitations fo recycling. In almost all cases, degradation is inevitable in the process of recycling. Even in the case of aluminium, can to can recyling is limited to some 70% due to this reason. http://www.alumi-can.or.jp/publics/index/65/ The case of metals for medals in Tokyo olympic here is misleading as the volume is significantly limited and the cost for recycling is significantly high. In addition, significant resource is necessary for recycling from collection, selection, cleaning, and processing to reclates. In case of plastics, not only degradation but also hygine consideration must not be neglected. The overall description in the chapter on recycling lacks in this situation and gives exaggerated rosy picture, mileadingly.	Accepted.	Shigetaka Seki	Consumer Product Safery Association	Japan
22977	11	29	16	28	I understand why this is there, but it appears to be an alternative explanation of what happens to the one offered in section 11.2.1. It is a production-based analysis but there are some references to scope 2(energy) and one slected scope 3 (transport, p.13, line 1) emissions. Maybe the exposition of the emissions data in the figures should come before the attempt to explain and analyse the trends offered in section 11.2.1.	No action needed. At page 16 (from line 29) the international trade and supply chain subsection address these concerns.	Edgar Hertwich	Norwegian University of Science and Technology	Norway
18845	11		21		Circular Economy is embraced as an approach simply because it is viewed as an important approach to achieving sustainable environmental and economic development (EMAF, 2015; EMAF, 2013; EMAF, 2012, COM, 2015, COM, 2014).	Agree	Michael Ugom	University of Nigeria, Nsukka	Nigeria
22973	11	29			reference needed	Accepted.	Edgar Hertwich	Norwegian University of Science and Technology	Norway
22975	11	37			Again, it is unclear whether that is whith respect to its own base value or as a share, i.e. percentage or pp.	Accepted. Clarification will be added.	Edgar Hertwich	Norwegian University of Science and Technology	Norway
33151	11				I trust that there are over productions for many sectors. Limit to production policy can be justified. For example, behaviour aspect of food and clothing wastage may have implication to climate change. Inddiviual celling or limit can be applied. It could be even voluntarily for some next ten years which help to generate individual awareness	Rejected. Those issues are to be covered in depth in the Chapter 5.	Edris Alam	Rabdan Acadmey	United Arab Emirates
38427	12	2	12	2	Suggest "shows that physical energy intensity dropped by 21% between 2000 and 2017" (if this is what is meant by "scaled down". Also, is this a global value? If so, please state. If not, please state.	Accepted. Physical indicator defined at p 111 would be used instead	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
38429	12	2	12	2	Now you introduce SEC, which is the same as physical energy intensity. Need to be consistent throughout.	Rejected. As modification will be made in reaction on comment above problem addressed in this comment disappears.	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
38431	12	3	12	5	Each time you use "by", I suggest you change it to "below", so that the sentence would read "Specific energy consumption (SEC) per ton of iron and steel production in 2017 was 6% below the 2000 level, 14% below for chemicals and petrochemicals, 37% below for cement, 20% below for pulp, paper and printing , 16% below for aluminum by 16%, and 16% below for other industries (IEA 2018)."	Accepted.	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
38433	12	6	12	8	Suggested re-write: "This progress is driven by improvements in technologies and practices, including adoption of best available technologies (BATs), improved operating practices, and by use of recycled materials which require less energy to process than raw materials." The improvements are not only from technologies, but also through better operating practices - optimization of energy use through simple procedures as well as through sophisticated computer programming. I suggest that you don't say that this is through new and highly efficient production facilities in China, India, and elsewhere because any new facility anywhere in the world will be better than an older one anywhere in the world when first installed, but then it will also depend on how it is operated. I've seen relatively advanced facilities in China where the control panels are not operating, so the staff has no idea of the operating parameters.	Accepted.	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
38435	12	9	12	12	Again, it would be good to also acknowledge how operating practices are also important. If industrial production was only a matter of using a technology, then these sentences would be correct. But industrial plants are complex, with interrelated operations, that still rely on humans and that require maintenance, etc. In my experience very few if any industrial facilities operate at their best practice level. Instead there are many leaks, broken components, lack of optimized operating conditions, etc.	Accepted.	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
13255	12	13	12	13	the list should include CCS	Rejected. The scope of the para on energy and material efficiencies, to which CCS does not belong	Asa Ekdahl	world steel association	Belgium
11377	12	18	12	18	'may by' would be 'may be'	Accepted. Thank you.	PINAKI SARKAR	CSIR-CENTRAL INSTITUTE OF MINING AND FUEL RESEARCH	India
34239	12	18	12	18	Shouldn't the last word of the line, 'by' be corrected for 'be' ? [suggestion ENSEEIHT INP]	Accepted. Thank you.	Antoine BONDUELLE	Climate Action Network France	France
11843	12	18	12	19	Please change "by" to "be" in this sentence. Should be "..average SECs for steel and aluminium may be halved by 2060."	Accepted. Thank you.	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
38437	12	30	12	38	AR6 is supposed to look at trends from 2010 to present, so the first few sentences are not needed. I suggest focusing on the details of the trends since 2010. This section also needs references.	Rejected. To show what is new since 2011 we need background to compare with. This is the only reason why limited data for earlier periods are presented.	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
13257	12	32	12	33	The collaps of the Soviet block manufacturing must have played a major role	Accepted. This is correct.	Asa Ekdahl	world steel association	Belgium
8921	12	34	12	34	Describe the "metrics" referred to.	Accepted. Will be clarified.	Johannes Morfeldt	Chalmers University of Technology	Sweden
38439	12	39	12	39	Suggest this sentence read: "Direct GHG emissions…" since chapter 2 doesn't include indirect GHG emissions.	Accepted. Thank you.	Lynn Price	Lawrence Berkeley National Laboratory	United States of America

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
38441	12	44	12	46	Yay! Thanks for adding the indirect emissions! Maybe start this paragraph with the total (direct and indirect) emissions, then break them out in the following sentences?	Rejected. Thank you. As direct emissions are more clearly defined and there are different approaches to estimate indirect one (which makes it less certain) we prefer to start from more certain number well coordinated with Chapter 2.	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
8923	12	39	13	2	What is meant by "waste"? Does it refer to use of waste products or does it refer to handling of materials at their end-of-life?	Accepted. Will make reference for definition either on chapter 2, or on glossary	Johannes Morfeldt	Chalmers University of Technology	Sweden
8967	12	39	13	2	It would be good if the text is clear on which emission sources that are considered in the estimations using the annotation of the Common Reporting Format (CRF) - the sector/activity codes. These are used in national reporting and should follow international methodological guidelines on greenhouse gas inventories.	Accepted. In the figure 11.4 caption we will make it more clear	Johannes Morfeldt	Chalmers University of Technology	Sweden
38443	12	39	13	2	This section needs references.	Accepted. References are located at figure 11.3, but may be duplicated in the body text as well.	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
38445	13	3	13	3	The first sentence is not needed.	Rejected. This is important general statement, which is illustrated by componets later in the text.	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
38447	13	3	13	10	This discussion is not clear to me and it doesn't help for me to refer to Figure 11.4a and Table 11.1 to understand what is being said here. Where do the % values come from? What is the difference between industrial fuel combustion and industrial processes? What is meant by emissions from products use and waste?	Rejected. In absolute values the contributions are at 11.4.e, but the text does not dublicate this, and presents relative (in %) contributon of major components.	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
13259	13	11	13	15	Wuld new production facilities not reduce the direct GHG emissions per unit of energy?	The relevance of the comment to the refered text is not clear.	Asa Ekdahl	world steel association	Belgium
38449	13	11	13	15	I'm unclear what the purpose of this paragraph is. The first 2 sentences are not needed, since AR6 should focus on trends since 2010. Do you mean to refer to Figure 11.2 or another figure? The last sentence doesn't make sense.	Rejected. To show what is new since 2011 we need background to compare with. This is the only reason why limited data for earlier periods are presented.	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
38451	13	18	13	23	Each time you mention emissions in this paragraph you should refer to them as direct GHG emissions since that is what is shown in Figure 11.4f.	Accepted. Thank you.	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
46793	13	18	13	23	This paragraph can lead to a misunderstanding. The increase in emissions in China and other Asian countries is linked to the economic growth of these countries, but also to the increasing demand and consumption of countries in the rest of the world, especially OECD countries. Final consumption of a significant part of China's industrial production has partially grown due to European demand. Some of the industry production has shifted from Europe to Asia, thus shifting GHG emissions as well.	Accepted, revised	Luis Javier Miguel González	University of Valladolid	Spain
18867	13	20	13	22	This sentence is confusing. What do you mean by saying "more evenly"? The text says "...emissions are distributed more evenly," yet the following wordings states that the shares continue to change ..So, we cannot say that it is evenly distributed..	Accepted, revised	Etem Karakaya	Independent researcher, former Profesor,fired with the decree of law since 2016	Turkey
11845	13	22	13	23	Could be written otherwise. Europe is also contributing to industrial GHG emissions, even though they are the only region with decreasing industrial emissions.	Accepted, revised	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
34243	13	22	13	23	Missing word ? Europe can't have a net-zero industrial emission of GHG. Furthermore, it's not quite rigorous to say that Europe emissions have been reduced, while Europe have delocated a part of its productions in other regions. Is there a "net" figure ? [suggestion ENSEEIHT INP]	Accepted, revised	Antoine BONDUELLE	Climate Action Network France	France
40271	13	22	13	23	revisit statement - this reads as Europe did not contribute to industrial GHG emissions - consider refering to growth	Accepted, revised	Vida Rozite	International Energy Agency	France
33013	14	0	14	0	This account of industrial emissions is highly confusing. 8Gt is the generally accepted figure of direct CO2 emissions for industry today. You need to be much clearer about what are direct and indirect emissions, which are CO2, which are CH4/N2O etc. Some of the categories of emisisons are also very unclear as to what they refer to (e.g. 'Other-IP' or 'Indirect N'). Are you sure you're not double-counting some of the emissions between 'manufacturing industries and construction' and some of the other sub-sector figures? Do waste GHG emissions include those from combustion for power/heat? If so, aren't these emissions from the power/fuel transformation sectors, not industry?	Accepted. In the figure 11.4 caption we will make it more clear with references to Chapter 2 on what is included. Those number incude waste as WGIII sesided to reflect it under industry	Peter Levi	International Energy Agency	France
38453	14	1	14	3	This is a very interesting and comprehensive figure which is not discussed enough in the surrounding text. I only found reference to 11.4a and 11.4f in the text. Can more text be added to discuss the key findings as presented in this figure?	Thank you. The intention was to make this figure together with following table self-speaking to escape much text describing trends which are visible and accounnied with numbers both on the plot and in the table.	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
38455	14	1	14	3	Figure 11.4d should be labeled (direct and indirect). Figure 11.4e should be labeled direct. Figure 11.4f should be labeled direct. What year is shown in Figures 11.4c and 11.4d? This should be noted. For 11.4e, please define IP, Other - IP, Indirect N, and Other. For Figure 11.4f, please fix the label so that the full text for South-East Asia and... shows. For the figure title, perhaps "Indirect emissions were calculated using..." would be better than assessed?	Accepted. Thank you.	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
38457	15	1	15	2	Please use periods instead of commas (e.g. 0.17% vs 0,17%) throughout.	Accepted. Thank you. Will adjust according to suggestions	Lynn Price	Lawrence Berkeley National Laboratory	United States of America

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
38459	15	1	15	2	Title should be "Dynamics and structure of industrial direct, indirect, and process GHG emissions". I understand these three categories, but I also see waste GHG, product use GHG, blast furnace, coke ovens GHG, and other non-CO2. These need to be defined - are any of them process GHGs (like blast furnace/coke ovens)? or non-CO2 (like waste)? For the average annual growth rates, you start the first column with 1971, the second column with 1991, and the fourth column with 2011, but the third with 2000 - should it be 2001?	Accepted. Thank you. Will adjust according to suggestions	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
38461	15	1	15	2	I cannot get the values to add up in the last column (2018 emissions). I see that there is a total for manufacturing which is the sum of the 6 rows below. But if I add what seems to be the totals for the other values (and don't include what seem to be non-total values), I can't come to the total below. Could you please make the values bold that add up to the total at the bottom?	Accepted. Thank you. Will adjust according to suggestions	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
38463	15	1	15	2	If I add 6206 + 5308 + 640, I get 12154 for the 2018 total direct and indirect GHG emissions, which is 60% of the total shown in this table (20090). I think it would be good to add a discussion about this 60% and the other 40%, clearly defining what they are comprised of.	Accepted. Thank you. Will check for the full consitency.	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
18507	15	1	15	28	the title of this paragraph is Economic Development. but most of the discussion is about urbanization. therefore, utbanization should be highlighted in the paragragh title.	Partially accepted. Yes urbanization is the main driver but also improvement of standard of living through increase of access to services	Jiahua Pan	Chinese Academy of Social Science	China
44823	16	11	16	13	The figures presented for the developed countries are very different from those for Belgium. In AR6: cement 15-30 tonnes/hbt. In Belgium: 500-600 kg/hbt, France: about 300 kg/hbt. Check the figures with e.g. Febelcem. In Belgium, estimated consumption of 2m² of concrete / hbt/year, i.e. 4 to 5 tonnes of concrete/hbt/year of which 500 kg cement/hbt/year.	Thank you, but the scope of the chapter and space limit prevents us from discussion for separate countries.	Véronique Waroux	Planète-A	Belgium
8925	16	15	16	22	Morfeldt et al. (2015) showed that demand for steel would stagnate in 2050 if all countries are assumed to reach the mentioned saturation level. This demand would also use up the full reserve of iron in the earths crust that is currently economically viable to extract. Morfeldt, J., Nijs, W., & Silveira, S. (2015). The impact of climate targets on future steel production – an analysis based on a global energy system model. Journal of Cleaner Production, 103, 469–482. https://doi.org/10.1016/j.jclepro.2014.04.045	Accepted, revised	Johannes Morfeldt	Chalmers University of Technology	Sweden
38465	16	19	16	21	Zhou et al., 2019 (https://doi.org/10.1016/j.apenergy.2019.01.154) shows the industry sector CO2 emissions peaking in 2020.	Accepted. Will consider this paper	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
22979	16	29	16	51	it is appropriate to include international supply chains, not only because of carbon leakage but because their emergence influenced how industrialization proceeded and how policies in one region can influence emissions in another region. The current presentation, however, lacks a clear message and does not utilize the literature very well. Given that trade is already included in section 11.2.1, the question is whether this is the right place to have this material. I think international trade is important because it (1) has enabled export-driven economic growth in some East Asian economies, which has lead to a rapid increase of emissions there, (2) has helped OECD countries to restructure their economies around services (and raw materials for Australia and maybe also Canada) and mostly helped to decarbonize. Trade-related emissions have peaked, as for example https://www.tandfonline.com/doi/full/10.1080/14693062.2019.1619507 (see also references therein) show, as a result of a slower growth of trade and a more rapid reduction of the carbon multiplier of exported products in emerging economies (ibid.)	Accepted, revised	Edgar Hertwich	Norwegian University of Science and Technology	Norway
34463	16	29	16	51	It would be relevant to add that international agreements sholuld include not only national emissions but also international transportation and carbon footprint	Rejected. Here is not right place to speak about such agreements. It mostly subject for policy chapters to address.	Emmanuel RAUZIER	NGO Association negaWatt	France
36375	16	29	16	51	It is not surprising that the CO2 enbedded in net import from non-OECD countries is equal to, or even greater than, the size of the OECD economies. The choice of international framework policies can make the change and should be analyzed, not necessarily in this chapter but in an appropriate place.	Agree that this discussion should be addressed in other places of the report.	Shigetaka Seki	Consumer Product Safery Association	Japan
8927	16	31	16	33	Emissions embodied in trade and "carbon leakage" are not the same. It should be clarified what is meant by carbon leakage here. Usually it refers to industrial activities relocating due to differences in national/regional climate policy. Emissions embodied in trade can give an indication to that this is happening, but does not mean that it's necessarily true (especially when considering embodied emissions as an aggregate for all manufactured products)	Accepted, revised	Johannes Morfeldt	Chalmers University of Technology	Sweden
8929	16	46	16	51	Sweden has a target specifying that national environmental policy cannot result in increased environmental problems abroad. The Swedish EPA has for several years used consumption-based emissions accounting as a complementary inventory to track progress with this target. http://www.swedishepa.se/Environmental-objectives-and-cooperation/Swedens-environmental-objectives/The-generational-goal/ http://www.naturvardsverket.se/Sa-mar-miljon/Klimat-och-luft/Klimat/Tre-satt-att-berakna-klimatpaverkande-utslapp/ (in Swedish)	Accepted, revised	Johannes Morfeldt	Chalmers University of Technology	Sweden
12975	16	49	16	51	Should expand on this point by providing a couple of examples.	Rejected. This is obvious conclusion from the assumption made and it is correct for any whether developed or developing country. See also comment below.	Robin White	Environment & Climate Change Canada, Government of Canada	Canada

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
22981	16	34			Complex global supply chains, in which intermediate inputs for export production are imported, hence embodied carbon crosses borders multiple times. Your quantification of emissions depends on whether you account only for the initial export, as the workstream starting with Peters&Hertwich (2008) does or whether you also include the multiple bordercrossings. The increasing unbundling of value chains may be relevant here as it indicates how production can reorganize in response to relatively small price differences, which may be relevant in relationship to carbon leakage (https://doi.org/10.1016/j.eneco.2019.104651). Potential policy mechanisms are border tax adjustments, which also influence these supply chains, and levies on embodied carbon at the place of consumption. My own work indicate that traded goods are, on average, more energy intensive than average goods, but at the same time, produced with less carbon-intensive energy than the arverage energy use. This may be relevant in context of the question of whether trade is good or bad for the environment, which unfortunately we do not yet have a good answer for.	Accepted, revised	Edgar Hertwich	Norwegian University of Science and Technology	Norway
38467	17	2	17	5	I like the 6 categories included here. One question: where does material quality fit in? One of the reasons that Chinese buildings, for example, have much shorter lifetimes than buildings elsewhere is the terrible quality especially of the cement/concrete used but also of other components.	Thanks for raising this point . Material quality is an important factor in the lifetime of products, which in turn affects material demand. For example, extending the lifetime of products, in part by using suerprior materials, leeds to overall reduction in the material requirements, and thus emissions. We will include this concept in Section 11.3.1	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
38469	17	19	17	19	Are you measuring material services as GDP? GDP is comprised of many services, not just those that depend on materials production. I'm confused by this, so I expect others will be also - please explain.	Conceptually, yes, we would measure material services as their effect on GDP. Of course, in practice, this is quite difficult to do (as you know), and unpicking maerial and energy services is challenging.	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
11847	17	21	17	21	Please include "of" in this sentence. Should be "..the delivering of goods and services…"	Corrected, thanks.	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
37551	17	24	17	24	The figure caption is inaccurate: global demand growth ...	This is the International Energy Agency's title. We will review this when permission is granted	Michiel Schaeffer	Climate Analytics	Netherlands
11849	17	25	17	25	Could the explanatory "(level off)" be included earlier in the chapter, where the term saturation is first used?	We will include this	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
11851	17	28	17	28	Please change "saturated" to "saturation" in this sentence. Should be "..had saturation developed between..."	Changed to "… had saturated levels between …"	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
25221	17	28	17	28	Delete "developed"	had saturated levels between	Eleni Kaditi	Organization of the Petroleum Exporting Countries (OPEC)	Austria
45395	17	7	18	16	Although demand of fresh/virgin materials have been discussed, it is worthwhile to also include a discussion about demand for scrap materials that can be recycled	Accept	Shareq Mohd Nazir	KTH Royal Institute of Technology	Sweden
24655	18	5	18	12	The saturation effect is important in many respects, but fails to hold in developed economies in at least two important ways. One is that, while developed countries with stable populations may have adequate infrastructure, that does not mean that this infrastructure is adaptable for a carbon-neutral economy. In this case, substantial material stocks will have to be retired and replaced before their end of life. The replacement of highways with high speed rail and gasoline infrastructure with electric charging stations are two such examples. In addition, there is one material that does not seem to conform to the saturation effect: plastic. Perhaps because of its short lifespan, or because the petrochemical industry is aggressively seeking out new uses and markets, demand for plastic, even within developed countries, continues to rise. Given the carbon footprint of cement (crucial to infrastructure) and plastic, these exceptions deserve mention.	Thanks for the comment. You raise an important point about the materials required to transition to a low-carbon economy. We will include this here, and in the discussion on lock-in of capital infrastructure, section 11.5.1. Consumption of plastics (not production) has saturated in the UK over the last decade, and stocks are expected to remain constant per capita out to 2050 in modelling.	Neil Tangri	GAIA	United States of America
38471	18	5	18	16	Very important points, but the one reference is old (AR6 should be using more recent references). Can you include more recent ones here?	Yes, will update include more recent references.	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
13261	18	14	18	16	Capacity building is cruicial for this to materialise	Agreed.	Asa Ekdahl	world steel association	Belgium
40223	19	18	18	18	vehicles isntead of vehciles	Corrected, thanks.	Ana Ines Fernandez	University of Barcelona	Spain
6067	19	1	19	1	There should also be a loop in the picture that in the design stage, products or parts of them should be planned easier to be recycled or reused.	Such a loop would be conceptual (a feedback of an idea) rather than a material flows. It would be confusing therefore to include this idea as a loop (like the green one). The design for use, long-life and reuse is covered in the blue box instead.	Andreas Oberheitmann	FOM University of Applied Sciences	Germany
8837	19	11	19	11	These references could also help for petrochemicals: doi.org/10.1126/science.1260352 ; doi.org/10.1126/sciadv.1700782 ; doi.org/10.1016/j.rser.2014.07.114 ; doi.org/10.1057/s41599-018-0212-7	Thanks, we will consdier these.	Saygın Değer	SHURA Energy Transition Center	Turkey
33015	19	11	19	11	The citation for steel looks wrong - it's a Cullen/Allwood paper. Their aluminium paper should also be listed here.	We are only allowed more recent citations …	Peter Levi	International Energy Agency	France
18805	19	14	19	14	Would be worth mentioning that IEAs flagship publication World Energy Outlook 2019 inludes a sub-chapter with calculations explicitly on industrial material efficiency.	The WEO (2019) has been included under the "changes to scenario modelling" paragraph (2 below)	Andreas Schroeder	International Energy Agency IEA	France

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
34247	19	18	19	18	Vehciles' instead of 'vehicles' [suggestion ENSEEIHT INP]	Corrected, thanks.	Antoine BONDUELLE	Climate Action Network France	France
18869	19	7	20	20	I would like to offer third option for IAMs and climate change scenario models to include possible material demand reduction opportunity. It can be simply called as "material-substitution possibility with other factors of production": Production theory in economics highlights the importance of substitution and complemantarity posibilities among factors of production. We can extend the number of production factors by including materials and energy alongside capital and labour as several recent studies considers such possibilty in the case of KLEM models. In this respect possibility of material substitution (as well as energy substitution) with other factors could lead to considerable amount of material demand reduction depending on the elasticity of substitution between factors (inputs). One specific study analysing material demand reduction with respect to elasticity of substitution with a translog model is carried out by Aidt et al (2017). Estimating input substitution possibilities might provide several insights in determining how to implement effective resource efficient low carbon development strategies at the industry level. Aidt et al. (2017) , for instance, found that there are considerable posibilities to substitute materials with capital and labour for various sectors for the United States. As elasticity of substitution is significant part of production theory and particularly CGE models extensively use the elasticity of substitution values in analysing counterfactual results, I believe future studies should seriously consider the possibility and implications of material demand reductions through factor substitutibility. Aidt, T., Jia, L., & Low, H. (2017). Are prices enough? The economics of material demand reduction. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 375(2095), 20160370.	Substitution will be discussed elsewhere	Etem Karakaya	Independent researcher, former Profesor,fired with the decree of law since 2016	Turkey
22983	19	9	20	9	Good paragraphs, very informative and citing lot's of relevant information, however, from a very limited geographical region. There is more evidence, especially from East Asia but also North America, which I think you should acknowledge. The cited review by Hertwich et al., completed ca. 1 year ago, contains some of that evidence which you might like to also cite here.	Thanks. We will add in a wider range of example papers, and include the Hertwich review paper.	Edgar Hertwich	Norwegian University of Science and Technology	Norway
34245	20	7	20	9	Maybe it could be useful to explain or at least precise why cars, cement etc are examples of dynamic materials models [suggestion ENSEEIHT INP]	Thanks, we will expand this section.	Antoine BONDUELLE	Climate Action Network France	France
40225	20	13	20	15	embedded instead of embed. Line 15: In Gruble et al.(2018) produces 1.5ºC…doesn't read well	Corrected, thanks.	Ana Ines Fernandez	University of Barcelona	Spain
12977	20	21	20	22	Figures need some text to describe context, including the nature of the scenarios.	Thanks, we will consider this.	Robin White	Environment & Climate Change Canada, Government of Canada	Canada
34249	20	22	20	22	The acronyms 'RTS' and B2DS' are not defined here nor in the glossary [suggestion ENSEEIHT INP]	Thanks, we will consider this.	Antoine BONDUELLE	Climate Action Network France	France
22985	20	10	29	22	Having looked at the cited IEA report, I do not completely understand how they work. Maybe the author of this paragraph has a better insight. My impression is that material efficiency is calculated in isolation of other aspects for product performance. Thereby, synergies between material and energy efficiency, for example through reducing the mass of vehicles or the size of buildings, is not captured. Potential trade-offs may also be left out. It is also not clear whether possibilities for substitution, apart from with a secondary material, are included. One of the crucial research gaps (not yet identified in the subsequent paragraph) is to ignore such potential interactions in particular when they occur across traditional sector boundaries.	Thanks, this is a good point. Inclusion of ME in scnearios is still being developed (as you are well aware). ME is treated exogenously in the IEA modelling, at present. There is some early research trying to bring ME indie the TIMES model, but it is challenging. For now, the trade-offs between ME and EE are hard to unpick. We will update the text to reflect this.	Edgar Hertwich	Norwegian University of Science and Technology	Norway
19265	21	4	21	4	Section 11.3.3 deals with circular economy, which is discussed in Chapter 5 (demand) and other chapters. Overlaps should be avoided and cross-referencing is encouraged.	Yes, indeed we should have internal coordination to avoid this.	Masahiro Sugiyama	University of Tokyo	Japan
29105	21	4	21	4	Section on circular economy also in Ch 5 (5.3.2.3). Please check for 'framing' overlap	We are going to check with other chapters to avoid such overlaps.	Minal Pathak	Ahmedabad University	India
27487	21	4	21	26	Add following reference: Singh et al 2016 provide further description about how circular economy advocates to reduce waste: various processes within the circular economy – repairing (fixing fault but with no guarantee), reusing (simple reuse without any modifications), refurbishing (aesthetic improvement with limited functionality improvements), reconditioning (potential adjustments to the item to bring it back to working order), recycling (extraction of raw material for use in new products) and remanufacturing (series of manufacturing steps acting on end-of-life part of product to produce as-new, better performing products with warranty). CE aims at phasing out waste from industrial systems and therefore the recovery routes focus mainly on recirculating post-consumer materials. CE recognises the important role of product design in disassembly, inspection, reassembly and eliminating the use of toxic chemicals. In other words, according to the 'hierarchy of resource use' proposed by Gharfalkar et al. (2015), CE resource recovery routes focus more on operationalising replacement and reduction (which is 'waste prevention' in the EU waste hierarchy), recovery (reuse by resale, repair, refurbish, reconditioning and remanufacturing) and reprocessing (up-cycling, re-cycling and down-cycling), and less on energy recovery and disposal (Table 2). Singh, Jagdeep, and Isabel Ordoñez. "Resource recovery from post-consumer waste: important lessons for the upcoming circular economy." Journal of Cleaner Production 134 (2016): 342-353. https://www.sciencedirect.com/science/article/pii/S0959652615018442	There are too many relevant examples. Due to words limit, we can only present several ones, but not all of them.	Mariel Vilella Casaus	Zero Waste Europe	United Kingdom (of Great Britain and Northern Ireland)
5841	21	5	21	6	Circular economy (CE) is one effective approach to mitigate industrial GHG emissions and has been widely promoted worldwide since AR5, "since AR5"is not correct, much early than that.	Accepted, it is now since AR4	Xiang Yu	Institute for Urban and Environmental Studies,Chinese Academy of Social Sciences	China
38475	21	5	21	26	There is much overlap between this paragraph and the one on page 12, lines 9-27. Please resolve.	Thank you. Accepted	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
11853	21	6	21	6	Please inlude "an" in this sentence. Should be "From an industrial point of view…"	We made the corresponding change here.	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
5843	21	7	21	8	suggest cited the following article to demonstrate the CE concept, Kirchherr J, Reike D, Hekkert M. Conceptualizing the circular economy: An analysis of 114 definitions[J]. Resources, conservation ,and recycling, 2017, 127: 221-232.	We do appreciate this suggestion, but due to limited room, we can only provide one widely accepted definition on CE although we believe that your suggested reference is also a very good one. We are also discussing this definition issue with other chapters so that we can avoid overlapping.	Xiang Yu	Institute for Urban and Environmental Studies,Chinese Academy of Social Sciences	China
5851	21	7	21	8	I suggest cited the following article to demonstrate the CE concept, Kirchherr J, Reike D, Hekkert M. Conceptualizing the circular economy: An analysis of 114 definitions[J]. Resources, conservation ,and recycling, 2017, 127: 221-232.	We do appreciate this suggestion, but due to limited room, we can only provide one widely accepted definition on CE although we believe that your suggested reference is also a very good one.	Xiang Yu	Institute for Urban and Environmental Studies,Chinese Academy of Social Sciences	China
11855	21	10	21	10	The established abbreviation "CE" should be used throuhgout this sub-chapter	Thank you. We have made all the changes based upon your advice.	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
22989	21	11	21	17	This sentence is an example for a statement not well supported by evidence.	Accepted	Edgar Hertwich	Norwegian University of Science and Technology	Norway
11857	21	19	21	26	This is a repetition of text from page 12.	Thank you	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
8931	21	21	21	26	Sounds promising, but there are limitations to secondary steel production since it alone won't be able to cover future demand, even when saturation of the in-use steel stock is taken into account and demand is adjusted when saturation occurs. See Morfeldt et al. (2015). Morfeldt, J., Nijs, W., & Silveira, S. (2015). The impact of climate targets on future steel production – an analysis based on a global energy system model. Journal of Cleaner Production, 103, 469–482. https://doi.org/10.1016/j.jclepro.2014.04.045	Limitations are now mentioned	Johannes Morfeldt	Chalmers University of Technology	Sweden
38473	21	24	21	26	Page 12, lines 24-26 say "While shifting globally in ore-based production from average to BATs can save 6.4 EJ yr-1, the saving potential of shifting to secondary steelmaking is 8 EJ yr-1, and limited mostly by scrap availability and steel quality requirements." But here it is repeated without the addition of the scrap availabilty consideration: "While shifting globally in ore-based production from average to BATs can save 6.4 EJ yr-1, the saving potential of shifting to secondary steelmaking is 8 EJ yr-1, and limited mostly by steel quality requirements (Gonzalez Hernandez et al. 2018c)."	Scrap availability now included	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
13263	21	26	21	26	and scrap availability	Unclear comment	Asa Ekdahl	world steel association	Belgium
38477	21	27	21	27	Which "systemic approach" is being referred to here?	Here we refer to circular economy.	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
27475	21	33	21	46	Include this discussion and final definition of the Circular Economy by Geissdoerfer et al. (2017): The most renowned definition has been framed by the Ellen MacArthur Foundation, introducing the Circular Economy as “an industrial economy that is restorative or regenerative by intention and design” (2013b: 14). Similarly, Geng and Doberstein (2008: 231), focusing on the Chinese implementation of the concept, describe the Circular Economy as the “realization of [a] closed loop material flow in the whole economic system”. Webster (2015: 16) adds that “a circular economy is one that is restorative by design, and which aims to keep products, components and materials at their highest utility and value, at all times”. Accordingly, Yuan et al. (2008: 5) state that “the core of [the Circular Economy] is the circular (closed) flow of materials and the use of raw materials and energy through multiple phases”. Bocken et al. (2016: 309) categorise the characteristics of the Circular Economy by defining it as “design and business model strategies [that are] slowing, closing, and narrowing resource loops”. Based on these different contributions, the definition of the Circular Economy is: "a regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling."	Since the concept of CE appears many times in IPCC AR6, we presume that it will be better to provide a more official definition of CE when it first appears. Chapter six also mentions this concept. We will have internal coordination to solve this problem. Here we would liek to remain our current description of CE.	Mariel Vilella Casaus	Zero Waste Europe	United Kingdom (of Great Britain and Northern Ireland)
13265	21	37	21	40	It is of course great that materails are recyclable but it is no guarantee that they will be recycled. A much more significant contribution would be if they used secondary raw materails or invested in recycling facilities	Here we just want to provide one example to say that at company level, careful product design can help achieve more recyclable material.	Asa Ekdahl	world steel association	Belgium
29123	21	43	21	46	Please check for prescriptive language	Not sure what we should revise here.	Minal Pathak	Ahmedabad University	India
5849	21	1	22	26	I suggest this chapter focus more on mitigation, for example, how the CE can reduce the carbon emission. How industrial park can reduce carbon emissions.Suggest cited the following article which, discusses CE in the industrial park can reduce carbon emissions.Yu X, Lu B, Wang R. Analysis of low carbon pilot industrial parks in China: classification and case study[J]. Journal of cleaner production, 2018, 187: 763-769.and Guo Y, Tian J, Chertow M, et al. Exploring Greenhouse Gas-Mitigation Strategies in Chinese Eco-Industrial Parks by Targeting Energy Infrastructure Stocks[J]. Journal of Industrial Ecology, 2018, 22(1): 106-120.	I can add one reference here, but not two, due to words limit.	Xiang Yu	Institute for Urban and Environmental Studies,Chinese Academy of Social Sciences	China
22987	21	4	23	8	This section is quite thin and needs to be both improved and shortened. It should be more concise, drawing on more of the avaiable evidence, and avoid statements that are not substantiated by a body of research that goes beyond a single, regionally focused paper. I would also be careful to name and cite corporations, I am not sure that is kosher.	After our group discussion, we presume that a corporate example is necessary. We also believe that we should find a famous company. Dow chemical is such a case.	Edgar Hertwich	Norwegian University of Science and Technology	Norway
36377	21	4	23	8	Please see the comment No.4 To facilitate recycling, a most effective measure is to design a system to make the collection, sorting processes economic. Combined with easy to conduct sorting at the site and collection with transport taking advangate of returning trucks, a practcal recycling method for wall papers, a very difficult product for recycling in the past, is being developed. https://doi.org/10.1007/s10163-018-0761-2	This is industry chapter. I read this paper and found that it may be more appropriate to cite it in the urban chapter.	Shigetaka Seki	Consumer Product Safery Association	Japan

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
30957	21	4	23	9	Food waste topic should be introduced there. It s importance should be beter highlighted also considereing SDG 12.3	We have one AFOLU chapter to discuss food wastes.	Pietro Bartocci	University of Perugia	Italy
22991	21	20			Repetition of p.12, L20-23	Thanks	Edgar Hertwich	Norwegian University of Science and Technology	Norway
6021	21				Regarding the Circular Economy principles. This is excellent, but there is an underlying problem that must be addressed. Circularity has in fact been declining in the global economy, not improving, because the rate of extraction is exceeding the rate of gains in circularity. It seems to me that the only way to ensure that we scale up circularity is to place caps on total material extraction (or, alternatively, but perhaps less effectively, to raise taxes on resource extraction).	Your view is correct at the global level, but at regional level, it may be different as some regions are facing challenges to get raw materials due to many factors. In such regions to encourage circularity still makes sense.	Jason Hickel	Goldsmiths, University of London	United Kingdom (of Great Britain and Northern Ireland)
5845	22	1	22	2	It's not correct and not be cited.	Not sure what we should revise here.	Xiang Yu	Institute for Urban and Environmental Studies,Chinese Academy of Social Sciences	China
5839	22	1	22	26	I suggest this chapter focus more on mitigation, for example, how the CE can reduce the carbon emission. How industrial park can reduce carbon emissions.Suggest cited the following article which, discusses CE in the industrial park can reduce carbon emissions. Yu X, Lu B, Wang R. Analysis of low carbon pilot industrial parks in China: classification and case study[J]. Journal of cleaner production, 2018, 187: 763-769. Guo Y, Tian J, Chertow M, et al. Exploring Greenhouse Gas-Mitigation Strategies in Chinese Eco-Industrial Parks by Targeting Energy Infrastructure Stocks[J]. Journal of Industrial Ecology, 2018, 22(1): 106-120.	We carefully read the two articles that this reviewer suggested. Unfortunately, both did not mention the contribution of CE to GHG emission reduction. Our focal point here is to present how CE can help reduce the overall GHG emission at meso-level, namely industrial park. We presume that industrial symbiosis is the most representative CE practise at this level. Thus, we added two new references from China and South Korea to present how eco-industrial parks can help mitigate the overall industrial emissions.	Xiang Yu	Institute for Urban and Environmental Studies,Chinese Academy of Social Sciences	China
22993	22	1	22	26	Much more research exists addressing eco-industrial parks and industrial symbiosis, including for emissions reduction. I do not have this at my fingertips. One relevant paper is doi:10.1111/jiec.12539. I would encourage the authors to make this more relevant to the present context or scrap it.	This reference is a book review. We do add one more Korean reference here to further present how industrial park can achieve GHG emission reduction.	Edgar Hertwich	Norwegian University of Science and Technology	Norway
27477	22	23	22	26	Develop further the information about climate benefits from waste prevention: waste avoidance and recycling reduce emissions associated with the production and delivery of goods by displacing virgin materials (USEPA 2006, USEPA 2009). Waste management strategies can trigger emissions reductions in other sectors (manufacturing, AFOLU), its mitigation potential may be greater than the total emissions from the waste sector (Hogg 2015). References: USEPA. (2006). Solid Waste Management and Greenhouse Gases: a Life-Cycle Assessment of Emissions and Sinks (p. 170). US Environmental Protection Agency; USEPA. (2009). Opportunities to Reduce Greenhouse Gas Emissions through Materials and Land Management Practices (p. 98). US Environmental Protection Agency; Hogg, D., & Ballinger, A. (2015). The Potential Contribution of Waste Management to a Low Carbon Economy. Eunomia. Retrieved from https://www.eunomia.co.uk/reports-tools/the-potential-contribution-of-waste-management-to-a-low-carbon-economy/	There are too many examples, but due to words limit, we can only cite several examples here.	Mariel Vilella Casaus	Zero Waste Europe	United Kingdom (of Great Britain and Northern Ireland)
27479	22	30	22	39	Urban symbiosos in the form of waste to energy incineration has been deemed as a net contributor to GHG emissions, even when the energy output is taken into account. (Hogg, 2006, 2015). Hogg, Dominic. "A Changing Climate for Energy from Waste?." United Kingdom: Eunomia Research & Consulting (2006). Hogg, Dominic, and Ann Ballinger. "The Potential Contribution of Waste Management to a Low Carbon Economy." Zero Waste Europe, Zero Waste France, ACR+, Eunomia Research & Consulting: Brussels, Belgium (2015).	We believe that this issue is region-specific. Our examples here show GHG mitigation benefits based upon LCA although we believe that some opposite examples may exist somewhere.	Mariel Vilella Casaus	Zero Waste Europe	United Kingdom (of Great Britain and Northern Ireland)
11859	22	38	22	38	"CO2" should be moved before "yr-1" and not be to the power of -1	Thanks	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
22995	22	39	22	47	I would appreciate if the authors distinguished hypothetical potential calculations from ex-post evaluations. Ex-post evaluations of circular economy measures are seldom, but I understand they exist for Japan, which has some of the World's best recycling systems. The reference I have is from Seiji Hashimoto, GLOBAL ENVIRONMENTAL RESEARCH 17(1), 2013. There is a particularily nice evaluation of the car recycling in Japan by Sato et al., 10.1016/j.apenergy.2019.01.002. However, it should be stated that the findings cannot be extrapolated to other regions because cars in Japan have a very short lifetime and reuse of parts is hence more relevant as they are less worn out.	Thanks. Language now nuanced but space constraint prevent from going to deep	Edgar Hertwich	Norwegian University of Science and Technology	Norway
11861	22	40	22	45	The established abbreviation "CE" should be used throuhgout this sub-chapter	We accept this and made corresponding changes.	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
40227	23	8	23	8	Tapia et al. Instead of Tapia Carlos et al.	Accept	Ana Ines Fernandez	University of Barcelona	Spain
38511	23	10	23	10	This comment is repeated from my earlier comments on the internal draft and pertains to the whole section on energy efficiency: This chapter (Chapter 11 WG3 AR6) refers frequently to the Energy Transitions Commission's 2018 Mission Possible Report. This report found that "Achieving net-zero CO2 emissions from the energy and industrial systems will require rapid improvements in energy efficiency combined with the rapid decarbonization of power and the gradual electrification of as much of the economy as possible." Exhibit 11 of the ETC report shows that energy efficiency can reduce emissions, reduce costs, and reduce the scale at which decarbonization technologies need to be deployed. This is an important point that is missed in this Industry chapter.	Understood points. Will see how to improve it.	Lynn Price	Lawrence Berkeley National Laboratory	United States of America

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
38479	23	14	23	15	Energy efficiency can be improved through improved practices as well as technologies. I suggest saying "…can be improved by various technologies and practices".	Agreed. Will revise it.	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
36785	23	15	23	18	quality of the figure must be improved	OK.	Vincenzo Spallina	University of Manchester	United Kingdom (of Great Britain and Northern Ireland)
38481	23	19	23	26	What is the purpose of these bulleted phrases? Most are relevant to this section on energy efficiency, but the last two are more relevant to earlier sections. I would remove the bullets and instead discuss each of the energy efficiency options in the text.	Agreed, but will see how to revise it (bullet or sentences.)	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
44825	23	22	23	23	Heat loss is a real challenge in cement plants. Successful examples of recovery should be provided.	Agreed but not new topic. No action.	Véronique Waroux	Planète-A	Belgium
38483	23	28	23	28	English needs improvement here.	Thanks.	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
38485	23	30	23	30	The potential thermodynamic (theoretical) minimum is *only* important in those relatively hypothetical cases where a new state-of-the-art plant is being built and it is being run as efficiently as possible every day of every year. These conditions rarely exist in the real world. There are many existing plants where technology upgrades can be made incrementally. There are many older existing plants that are not operated efficiently as possible. There are new state-of-the-art plants that are not operated efficiently as possible. The theoretical minimum is an interesting academic concept, but this report should be discussing the real-world situation.	Not fully agreed. Theoretical value is also important to see possibility for realization....but will consider how to mitigate the emhasis on that point.	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
38487	23	30	23	32	It is fine to say that the energy saving effect of secondary used material is important (it is!), but the second part of the sentence is just too broad given the limited evidence presented in Figure 11.9. See my comments on Figure 11.9 below.	Partly agreed. Will revise it.	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
18871	23	10	24	6	The text has to mention energy efficiency improvements are declining globally as the IEA emphasize..needs to discuss why it is declining and how it can be improved further..or is it coming to saturation in terms of energy efficiency? Reference: IEA (2019). Energy Efficiency 2019. IEA, Paris https://www.iea.org/reports/energy-efficiency-2019	Agreed. Will add some phrase.	Etem Karakaya	Independent researcher, former Profesor,fired with the decree of law since 2016	Turkey
22997	23	11			Please avoid concluding in the first centence.	Thanks	Edgar Hertwich	Norwegian University of Science and Technology	Norway
37553	24	8	24	29	Utilization of waste heat is quite a crucial area for reducing industry energy use and emissions. More detail discusion of available options and sector-specific applications are needed.	Will see page limitation and balance.	Michiel Schaeffer	Climate Analytics	Netherlands
45865	24	8	24	29	NEDO (New Energy and Industrial Technology Development Organization) has been conducting a "Research and Development Project for Innovative Thermal Management Materials and Technologies" since 2015.(NEDO 2019)	Thanks. Will check it.	MASANORI KOBAYASHI	New Energy and Industrial Technology Development Organization (NEDO)	Japan
22999	24	9	24	29	This section is confusing and maybe too technical for this report. I am not clear when you talk about temperature whether it is the temperature that is needed or the temperature at which waste heat is rejected. I think you talk about process integration, but I wonder whether a shorter paragraph with references to relevant literature would not suffice. i wonder whether these are not issues that were already well understood at the time AR5 was written. Please try to support your concluding statements with more than a single reference and make sure there is agreement in the relevant literature.	Will try to revise it for more clear explanation.	Edgar Hertwich	Norwegian University of Science and Technology	Norway
38489	24	9	24	29	I suggest you review this article to see if it would be helpful for this paragraph: Lu, H., L. Price, Q. Zhang. 2016. “Capturing the Invisible Resource: Analysis of Waste Heat Potential in Chinese Industry,” Applied Energy, Volume 161: 497-511. doi:10.1016/j.apenergy.2015.10.060.	Thanks. Will check it.	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
19789	24	20	24	22	The review of Arpagaus (2018) contains comprehensive information about high temperature heat pumps and this citation could be used to include more specific information about this technology (in my opinion).	Thanks. Will check it.	Adrián Mota-Babiloni	University Jaume I of Castellon	Spain
19791	24	27	24	29	Mentioned fluids are the most efficient for ORC at specific range of temperatures and it should be mentioned. If this range varies, other working fluids are the most efficient. Moreover, if you check reviews from ORCs other fluids are mentioned as the most efficient and most currenlty used today.	Agreed. Will add the conditions for the case.	Adrián Mota-Babiloni	University Jaume I of Castellon	Spain
38491	24	31	24	31	This section could be improved by including a discussion of ISO 15001 and its impacts. For some information, see: https://industrialapplications.lbl.gov/content/energy-management	Thanks. Will check it.	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
45867	24	31	24	42	Digital optimization for energy efficiency and conservation in factory (ERIA 2016), Exploring Energy Saving Potential for Industrial Sector Using Factory Energy Management System in Iida, Y., S. Inoue, and Y. Li ed s .), Study on the Advancement of the Energy Management System in the East Asia Summit Region ERIA Research Project Report 2015 17 ,) Refer to "https://www.eria.org/RPR_FY2015_no.17_Chapter_3.pdf"	Thanks. Will check it.	MASANORI KOBAYASHI	New Energy and Industrial Technology Development Organization (NEDO)	Japan
8839	24	44	24	44	This paper: doi:10.1016/j.energy.2011.08.025 quantifies an industry-wide energy efficiency potential from implementing Best Practice Technologies of 27% +/- 8%.	Thanks. Will check it.	Saygın Değer	SHURA Energy Transition Center	Turkey
38493	24	44	25	12	This seems to be a random discussion of selected technologies of varying impact and importance. I would remove this and develop a more comprehensive paragraph covering technology progress for the industry sector.	Partly agreed. Author, myself has similar impression. There were few truly progressed technology in EE area since 2013, so it seemed that they were randam. Will remove the details and have a few sentences that indicates the situation in academic journals.	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
42069	24	31			The relevance of energy storage and power electronics (efficient power supply, motor control, induction heating, power factor correction, active filtering) in electrification of energy should be acknowledged.	Will see how to revise it.	Francisco Javier Hurtado Albir	European Patent Office	Germany
9623	24	45			The text in 11.3.4.3 seems highly specific to one example - presumably there are multiple examples that are interesting in this topic.	Will try to revise it.	David Sholl	Georgia Institute of Technology	United States of America
40229	25	12	25	13	Figure 11.9 is unreadable, the font size is too small for numbers and letters	Accept	Ana Ines Fernandez	University of Barcelona	Spain

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
12979	25	12	25	14	Figures need accompanying text to assist in interpreting figures.	Accept	Robin White	Environment & Climate Change Canada, Government of Canada	Canada
36787	25	12	25	15	the figure is too small and not readable. Consider to modify	Accept	Vincenzo Spallina	University of Manchester	United Kingdom (of Great Britain and Northern Ireland)
44827	25	13	25	13	Figure 11.9 unreadable	Accept	Véronique Waroux	Planète-A	Belgium
33017	25	13	25	14	Need to clarify the boundary of the figures given, particularly for chemicals - including feedstock or not?	Accepted	Peter Levi	International Energy Agency	France
38495	25	13	25	15	Since all of the graphics do not provide BATs, the title for this figure should be changed to something like: "Energy intensities comparied to best available technologies, averages, minimums, and maximums." For the metals comparison chart: 1) are the units GJ/t crude steel? or GJ/t rolled steel? or something else? - please define. 2) for crude steel you show average for 2009 (sorry if this is incorrect - it's difficult to read) and 2017. Are these average GJ/t crude steel for all steel making processes? 3) its hard to read, but I believe that the next 3 bars are BF-BOF, (something illegible) EAF, and SR-EAF, followed by Scrap-EAF. Why is Scrap-EAF a darker bar? 4) the last crude steel bar is labeled BAT, but for what type of production? All crude steel regardless of production path? Or BAT for BF-BOF only? It can't be BAT for scrap-EAF because it is a higher intensity value. This BAT needs to be clearly labeled so the reader knows what to compare it to. 5) for aluminum, what process are the average and min and max values for? Is this only for primary prodction or for primary and recycled production together? 6) for aluminum, why is the bar for recycled darker? 7) for copper, you don't provide any BAT value, so perhaps remove this or find a BAT value? For the cement and clinker chart: 8) what is the unit? GJ/t cement? GJ/t clinker? It's very important and makes a difference with these products! 9) for the cement values (not the cement-electricity values) are these just for fuels or is this fuels + electricity? 10) for the cement-electricity label, I recommend adding kWh/t in the text (e.g. Cement-electricity (kWh/t, right axis). Also t of what? cement or clinker - needs to be added. Then also add % in the clinker to cement label (e.g. Clinker to cement ratio (%, right axis). For the chemical chart: 11) what are the units? t of what? 12) write out HVC somewhere 13) no BATs available?	Thanks will be clarified	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
38497	25	13	25	15	I think that the title of this figure implies that these industries are approaching BATs, which it does not show. First, not all of the materials covered even have BATs presented (see my comment above about changing the title to better describe what these graphs actually show). Second, where a comparison of current average to BAT can be made, the findings are interesting and could be discussed in the text. For example, for crude steel, assuming the average for the early year (2008?) and 2017 can be compared to the BAT value provided, the text could explain that little progress has been made in improving the energy intensity of crude steel production between 2008? and 2017 (the values appear to be slightly above 20 GJ/t in 2008? and just about 20 GJ/t in 2017), while the BAT value of about 10 GJ/t implies significant improvement potential remains (e.g. the crude steel intensity is not "approaching BAT"). Additional text about aluminum and alumina production (probably only need aluminum) could be included. It's not possible to say anthing about copper since no BAT is included nor is any earlier year. Also for ammonia and methanol the distance from the 2017 average to the minimum value seems to be almost a halving of energy intensity.	Noted.	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
38499	25	17	25	22	You should include a caution, though, about timing. China, for example, won't decarbonize its grid for decades, so pushing for electrification of industial processes in China could actually increase emissions until the grid is less carbon-intensive. So near-term electrification - which is normally viewed as a "good" strategy - is actually extremely detrimental in terms of increasing CO2 emissions for countries like China.	Thank you, your point is fair, a cautionary note will be added.	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
38513	25	17	25	22	This comment is repeated from my earlier comments on the internal draft (I know it is a repeat of an earlier comment I provided above, but now I realize that it was not addressed last time, so I want to emphasize it: In this section, please acknowledge that electrification is only an option to reduce emissions if the electricity is low or zero carbon. In China, for example, electrification will not help to decarbonize industry if the electricity is coming from the grid for decades. Only with dedicated non-fossil electricity will this option be viable. It would be very interesting to see a discussion here of when the grids in countries with major industrial sectors will be more than 50% non-fossil or some sort of analysis of when electrification would lead to decarbonization. It should be acknowledged that in the meantime - as we wait for these countries to decarbonize their electricity grids - other available options (e.g. demand reduction, energy efficiency, material efficiency) should be fully pursued.	Thank you, as earlier, your point is fair, a cautionary note will be added.	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
38991	25	19	25	19	Replace "constructed synthetic net-zero GHG hydrocarbons" by " Cabon based synthetic fuels"	We may not use exactly this, but we will adjust the terminology for maximum clarity.	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
13267	25	20	25	20	or biomass with CCS	We will add this into the sentence.	Asa Ekdahl	world steel association	Belgium

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28011	25	20	25	20	IPCC states that fossils fuels with CCS is an option for industry. However, 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 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 both result in air pollution and mining increases. In other words, capturing CO2 from industry (a) reduces only CO2 but not air pollution or fuel mining and (b) has an equipment and energy cost. Using the same money for equipment and energy to replace coal or gas electricity with wind or solar eliminates more CO2 and also eliminates air pollution and mining. As such, using CCS for industry is always an opportunity cost. Similarly, 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. Please clarify that CCS/U is not an option for climate mitigation and is instead an opportunity cost in terms of climate, air pollution, and land degradation.	We need to include this in the dicussion on CCU/CCS, that there is a vigourous debate on its viabiliyt for a wide range of reasons, without taking a position. And noting that it is one of only several strategies.	Mark Jacobson	Stanford University	United States of America
33019	25	20	25	20	I would not describe the application of CCUS as fuel switching. This is a whole host of different technology arrangements and needs to be dealt with seperately, similarly to hydrogen.	The net-zero energy carriers can be potentially MADE with fossil plus CCS.	Peter Levi	International Energy Agency	France
28013	25	27	25	28	The IPCC states, "The coal to natural gas switch for electricity production and associated decline in direct GHG intensity in regions with natural gas (e.g. the United States) provides evidence of the effectiveness of fuel switching as a mitigation strategy." Please correct this, since the coal to gas switch reduced only CO2, but increases CO2e, which includes methane, black carbon, NOx, and SOx. See Table 3.1 of https://web.stanford.edu/group/efmh/jacobson/Articles/I/NatGasVsWWS&coal.pdf which compares the 20- and 100-year CO2e from coal, natural gas combined cycle, and natural gas open cycle. The errors in IPCCs assumption are that IPCC ignores entirely the masking effects of sulfate and nitrate aerosol particles from coal as well as the methane leakage. As a result, IPCC comes to the entirely wrong conclusion regarding coal versus gas on CO2e. In fact, both coal and gas are bad for climate and for air quality.	We can note that while the coal to NG swithc reduced CO2 emissions, there is debate about the full GHG impacts of the coal to NG switch.	Mark Jacobson	Stanford University	United States of America
37555	25	31	25	31	it is not only demand response. It provides both demand response and various new, cost-effective, long-term storage options (e.g. hydrogen storage, fuel storage)	This will be expanded to include the energy storage element.	Michiel Schaeffer	Climate Analytics	Netherlands
42071	25	35	25	37	The relevance of energy storage and power electronics (efficient power supply, motor control, induction heating, power factor correction, active filtering) in electrification of energy should be acknowledged.	This will be expanded to reflect these elements.	Francisco Javier Hurtado Albir	European Patent Office	Germany
38993	25	38	26	8	"Much of industry is electrified already in that most industry has switched to electric motor drive from other forms of mechanical drive." => This sentence is neither correct gramatically nor scientifically and references are lacking. Most of the high heat industries are not able to run with electricity, especially the cement, iron and steel sectors. These industries are as well the greatest emitters, thus other options than electricy have to be found to decrease industrial emissions. The switch to CO2-based synthetic fuel (e.g.e-methane) is the most likely candidate to decrease strongly and at short-term the CO2 emissions from these industries and to defossilize their systems. 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). (Fasihi et al., 2017, J. of Cleaner Production, 224, 957-980./DENA, 2017, The potential of electricity-based fuels for low-emission transport in the EU: An expertise by LBST and dena (German Energy Agency)./Artz et al., 2019: Sustainable Conversion of Carbon Dioxide: An Integrated Review of Catalysis and Life Cycle, Assessment, Chem. Rev., 118, 2, 434-504./CONCAWE, 2019: A look into the role of e-fuels in the transport system in Europe (2030–2050) (literature review), CONCAWE.)	This critcism is taken out of context, but understandable in that we were not clear we were referring to motor drive applications. In the main, we agree with the other points and will clarify the section.	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
37559	25	16	27	12	Electrification and fuel switching is a broad area and very sector-specific. Structuring this section into a few sbsections and more focused, sector-specific discussion of available options and potentials could make this part more informative and understandable to the reader.	Thank you. We do deal with the sectors more specficially later, but the decision was made to have a more general assessment of strategies here.	Michiel Schaeffer	Climate Analytics	Netherlands
33021	25	16	28	46	This electrification and fuel switching section needs a re-think as to what is included. At the moment it includes partial discussion of virtually every mitigation option aside from demand-side measures. This isn't a helpful categorisation, and it means that previous and subsequent sections repeat the content. I would suggest a re-structuring based on more specific subsets of mitigation options to avoid repitition and confusion. I would suggest breaking the section up into: bioenergy, fossil fuel switching, direct electrification, indirect electrification via hydrogen and hydroge-rich fuels etc.	Thank you, this is a useful structural suggestion that we will consider as we rewrite the section for the SOD.	Peter Levi	International Energy Agency	France
45869	25	16	30	2	Regarding the fuel switcing, one of the most challenging "fossil fuel utilisation approches" is "Carbon Recycle", initiated by Ministry of Econom, Trada and Industry, Japan with Carbon Recycling 3C. The Carbon Recycling 3C initiative aims to use CO2 as a fuel and material, and includes 3 specific actions to be undertaken toward this end. The initiative will accelerate technological development based on the Roadmap for Carbon Recycling Technologies announced at the G20 Energy and Environment Ministers' Meeting in June, and will promote innovation while cooperating with other countries. Initiative (2019). Refer to 'https://www.meti.go.jp/english/press/2019/pdf/0925_001.pdf'	We will include conisderation of this initiative in our section relating to CO2 utlization.	MASANORI KOBAYASHI	New Energy and Industrial Technology Development Organization (NEDO)	Japan
45871	25	16	30	2	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"	We will include conisderation of this initiative in our section relating to CO2 utlization.	MASANORI KOBAYASHI	New Energy and Industrial Technology Development Organization (NEDO)	Japan

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38995	26	16	26	16	In this sentence the role CCUS is not clear. This term should not be used as such, but be replaced by CCU or CCS. In this context, CCS and CCU do not play at all the same role. CCU plays a role in producing carbon feedstock as it allows the conversion of captured CO2 into products (e.g. chemicals), while CCS would allow to stored the CO2 emitted when fossil fuel is combusted. (Cuéllar-Franca and Azapagic, 2015, Bruhn et al., 2016, Arning et al., 2019) (Bruhn et al., 2016, Environmental Science & Policy, 60, 38–43./Arning et al. 2019, Energy Policy, 125, 235–249./ Cuéllar-Franca and Azapagic, 2015, J.CO2.Utili., 9, 82-102.)	This will be answered along with the other CCU/CCS questions	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
37557	26	20	26	30	It should be considered using hydrogen produced by electrolysis or other synthetic fuels (so-called electrofuels) is also kind of electrification. Regarding the terminology, it needs be clearly dfferentiated beween direct electrification through (direct) use of electriicity and indirect electrification through use of hydrogen or other synthtetic fuels throughout the text.	Agreed.	Michiel Schaeffer	Climate Analytics	Netherlands
13269	26	21	26	24	it is worth pointing out that mearly heat is not enough for steel production, carbon is used as a reducing agent to remove the oxygen from the iron ore	Will be clarified. And the reducing agent is hydrogen in the hydrogen Dri process.	Asa Ekdahl	world steel association	Belgium
38997	26	24	26	27	Here again CO2 based synthetic fuels (especially e-methane) are forgotten in the discussion while they can plan a key role without changes in infrastructures. 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. 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). (Anwar et al., 2020, J. of Env. Manag., 260, 110059./ Artz et al., 2019: Sustainable Conversion of Carbon Dioxide: An Integrated Review of Catalysis and Life Cycle, Assessment, Chem. Rev., 118, 2, 434-504./Byrnolf et al., 2018, Renewable and Sustainable Energy Reviews, 81/2, 1887-1905./Grinberg Dana et al., 2016, Angew. Chem. Int. Ed. 2016, 55, 8798 – 8805./Hepburn et al., 2019: The technological and economic prospects for CO2 utilization and removal, 575, 87-97.)	This can be amplified.	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
45399	26	25	26	26	Can also mention about the advanced reforming methods to produce cheaper blue H2 with CCS. Refer the recently published paper "Pathways to low-cost clean hydrogen production with gas switching reforming" which deals with producing H2 from natural gas with CCS and price lower than conventional steam methane reforming	This can be amplified.	Shareq Mohd Nazir	KTH Royal Institute of Technology	Sweden
40273	26	31	26	31	"Electrification requires more electricity" is a bit obvious	OK	Vida Rozite	International Energy Agency	France
37561	26	31	26	48	Electrification of various industry sectors would clearly raise the electricity demand but with the perspective of future scenarios with significant share of variable renewable sources, electrification of industry sectors could simultaneously reduce significantly the power curtailment, the renewable power which would be wasted without such additional flexibility (demand response and storage) provided through sector coupling with industry. When talking about quantitative information on increase of electricity demand due to electrification it would be useful to also provide information about the reduced curtailment/wasted power achieved through sector coupling.	The curtailment levels depend on how the power is made, the adjustability of demand, and the potential for absorbuing surplus wind and PV power as hydrogen and hydrogen derivatives.	Michiel Schaeffer	Climate Analytics	Netherlands
8841	26	36	26	36	Please see the following new paper that investigates the global role of renewables-based H2-DRI route, with particular focus on Australia-Asia trade for transition to cost-effective green steel production: doi: 10.1111/jiec.12997	Good new reference, thank you. To be included	Saygın Değer	SHURA Energy Transition Center	Turkey
11863	26	46	26	46	It should be clarified that it is the UK industry that is consuming 300 TWh.	OK	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
9625	26	31			It would be helpful that industrial electricity typically needs to be baseload-like (i.e. that simply supplying the electricity from intermittent sources is not sufficient)	This will be clarified; another section talks about potenital demand response in indsutry.	David Sholl	Georgia Institute of Technology	United States of America
38999	27	2	27	2	replace "synthetic hydrocarbon" by CO2 based synthetic fuels. These alternative fuels are not well discussed in the report, but also every time it is listed somewhere, different terms are used, so that is difficult to understand for the reader.	The language around synthetic hydrocarbon fuels will be harmonized, including a discussion of carbon sources.	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
40231	27	4	27	4	(Materials Economics 2019) instead of Materials Economics	Editorial comment	Ana Ines Fernandez	University of Barcelona	Spain
38501	27	4	27	12	For these costs, please provide the region for which they are relevant (the EU? the UK?) and provide in US$ (or whatever standard currency is being used for AR6).	Noted, thank you	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
39001	27	4	27	12	Please add: Hepburn et al. shows that CO2 utilization pathways, e.g. in concrete building materials are estimated to remove, utilize and store between 0.1 and 1.4 Gt CO2 yr−1 over the long term—with the CO2 sequestered well beyond the lifespan of the infrastructure itself—at interquartile breakeven costs of −$30 to $70 per tonne of CO2. (Hepburn et al., 2019: The technological and economic prospects for CO2 utilization and removal, 575, 87-97.)	Noted thank you. The section is not about sequestration.	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
39885	27	14	27	14	Regarding electrification of hydrogen production and the CO2 reduction it could provoke : hydrogen production based on about 30 TWh electricity per year could reduce CO2 emissions by about 6 MtCO2 per year compared to methan-based hydrogen production (analysis taking into account interconnected Europe). Analysis to be published at the IAEE 2020 conference, Le-Du, Tejeda and Françon, 2020.	Hydrogen box needs to be rewritten. Thank you, points taken, we will attempt to include this.	Bianka SHOAI-TEHRANI	RTE, CentraleSupelec	France

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
39003	27	15	27	20	This first paragraph lack adequate references as referring to a report from a lobby does not seem acceptable in a report from the IPCC. Especially as this vision does not encompass the numerous articles from the literature that are clearly stating that switching to a global industrial H2 economy in the coming decade is not feasible.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). (IEAGHG, 2019a: Putting CO2 to Use – Creating value from emissions, International Energy Agency./ 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./ 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.)	Hydrogen box needs to be rewritten. Thank you, points taken, we will attempt to include this.	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
38503	27	15	27	26	This sounds like a hydrogen promotion advertisement, not a scientific review of the potentials and issues. Please revise.	Hydrogen box needs to be rewritten. Thank you, points taken, we will attempt to include this.	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
29125	27	19	27	20	Might be useful to mention the year and also under what scenario	Hydrogen box needs to be rewritten. Thank you, points taken, we will attempt to include this.	Minal Pathak	Ahmedabad University	India
25223	27	20	27	20	Delete "it is "the new oil""	Hydrogen box needs to be rewritten. Thank you, points taken, we will attempt to include this.	Eleni Kaditi	Organization of the Petroleum Exporting Countries (OPEC)	Austria
11379	27	29	27	29	'Fuels refining' would be 'Fuels' refining'	Accepted	PINAKI SARKAR	CSIR-CENTRAL INSTITUTE OF MINING AND FUEL RESEARCH	India
12345	27	39	27	40	Please consider to include after this sentece the following: "Converting hydrogen to hydrogen-based fuel such as methane and methanol require life cycle analysis (LCA) in order to ensure decarbonization."	Noted, thank you for the suggestion	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
17105	27	14	28	45	Would be good to say something on the cost-effectiveness of (green) hydrogen in different applications. High for ammonia and methanol, low for steel.	Noted, thank you for the suggestion	Kornelis Blok	Delft University of Technology	Netherlands
17107	27	14	28	45	Why is nothing said about the simple use of hydrogen for heating (boilers and furnaces)? This is by far the largest potential applications. And it is probably more interesting to replace natural gas in boilers by hydrogen than much cheaper metallurgical coal in steel plants.	It is, but not explicit	Kornelis Blok	Delft University of Technology	Netherlands
23033	27	14	28	45	Much of what is presented here is also in the main text. Repetitive.	Hydrogen box needs to be rewritten. Thank you, points taken, we will attempt to include this.	Edgar Hertwich	Norwegian University of Science and Technology	Norway
29063	27	14	28	45	Useful content. Introduction to the box is journalistic style and relies on few sources. Needs more literature to substantiate.	Hydrogen box needs to be rewritten. Thank you, points taken, we will attempt to include this.	Priyadarshi Shukla	Ahmedabad University	India
38505	27	41	28	8	Please include references in this paragraph	Hydrogen box needs to be rewritten. Thank you, points taken, we will attempt to include this.	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
5731	27	45	28	1	"Extraction of hydrogen from biomass" - do you mean gasification, followed by reforming and shift, with integrated CCS? If so, say so, you aren't just extracting the hydrogen. The worst bit here is "presumably more costly". Electrolysis can be intensely expensive at low load factors. I'm just assessing a (sadly confidential) document that has biomass with CCS coming in 50 % of the price of electrolysis with wind. The point is that the "presumably" is not justified.	Hydrogen box needs to be rewritten. Thank you, points taken, we will attempt to include this.	paul fennell	Imperial College	United Kingdom (of Great Britain and Northern Ireland)
42073	27	12			The issue of electrification is illustrative of the problematic of electrification of heavy industries. The type of loads introdudce frequently reactive power deviations and low frequency harmonics that reduces efficiency of power transmission in the power netwpork. As already indicated, power electronics is a crucial techology for the necessary step towards electrification	Hydrogen box needs to be rewritten. Thank you, points taken, we will attempt to include this.	Francisco Javier Hurtado Albir	European Patent Office	Germany
38507	28	17	8	45	These two paragraphs only have one reference. Please provide additional references from recent peer-reviewed literature.	Hydrogen box needs to be rewritten. Thank you, points taken, we will attempt to include this.	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
5733	28	9	28	9	largest volume chemical, not "largest" chemical	Noted, thank you	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
39005	28	17	28	17	Here it should be stated that clearly that the discussion goes over CCU. The goal of using captured CO2 is not to "decarbonize" the process, but to DEFFOSSILIZE it. This mistake is often done, but it is important to make it clear. Also the role of e-methane should be discussed as it is is one of the only alternative to fossil fuel that can be deployed quickly by the industry without changes in infrastructure. More information: Two types of fuels can be generated via the power to fuel concept: 1) Synthetic gas (e.g. e-methane) so-called Power-to-Gas and 2) synthetic liquid fuels (e.g. methanol, ethanol), so-called Power-to-Liquid. In both cases, captured 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 (Ampelli et al., 2015, CCES, 2019). (Ampelli et al., 2015: CO2 utilization: an enabling element to move to a resource and energy-efficient chemical and fuel/ CCES, 2019: Carbon Utilization – A vital and effective pathway for decarbonization, Center for Climate and Energy Solutions../Anwar et al., 2020, J. of Env. Manag., 260, 110059./ Dimitrou et al., 2015, Energy Environ. Sci, 8, 1775-1789./Fasihi et al., 2017, J. of Cleaner Production, 224, 957-980/Sternberg and Bardow, 2015, Energy Environ. Sci. 8, 389–400./Breyer et al., 2015, Energy Procedia, 73, 182-189).	Thank you for the extensive comment. The language and referencing around CCU/CCS and synthetic fuels will be revised throughout.	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
20483	28	17	28	27	DACCU for MeOH and in particular FT fuels is described in Breyer et al. (https://www.cell.com/joule/fulltext/S2542-4351(19)30413-1) partly based on Fasihi et al. (https://www.sciencedirect.com/science/article/pii/S0959652619307772), while Cement CCU and PtX is discussed by Farfan et al. (https://www.sciencedirect.com/science/article/pii/S0959652619302185)	Hydrogen box needs to be rewritten. Thank you, points taken, we will attempt to include this.	Christian Breyer	LUT University	Finland
8843	28	28	28	45	Please see the following new paper that investigates the global role of renewables-based H2-DRI route, with particular focus on Australia-Asia trade for transition to cost-effective green steel production: doi: 10.1111/jiec.12997	Noted thank you	Saygın Değer	SHURA Energy Transition Center	Turkey
8933	28	28	28	45	Don't you mean "grey hydrogen to green hydrogen"? Isn't green hydrogen produced through water electrolysis which could be using electricity generated from renewable resources, so why would you use of syngas reduce CO2-emissions? Also, if syngas is produced based on capture carbon dioxide from fossil fuels, it means that the system is not carbon neutral.	Hydrogen box needs to be rewritten. Thank you, points taken, we will attempt to include this.	Johannes Morfeldt	Chalmers University of Technology	Sweden
8969	28	28	28	45	Avoid calling DRI-EAF production the "electric route" in this context. The "electric route" is generally associated with secondary production based on scrap. The route you are referring to is usually referred to as the DRI-route (direct-reduced iron). Or perhaps DRI-EAF.	Hydrogen box needs to be rewritten. Thank you, points taken, we will attempt to include this.	Johannes Morfeldt	Chalmers University of Technology	Sweden
8971	28	28	28	45	The Swedish steel industry companies are abbreviated LKAB and SSAB.	Noted thank you	Johannes Morfeldt	Chalmers University of Technology	Sweden
13271	28	30	28	30	I think what is meant by the "electric route" is in fact DRI +EAF commonly "DRI route". Electrical route would rather refer to scrap use in the EAF or "EAF route"	Hydrogen box needs to be rewritten. Thank you, points taken, we will attempt to include this.	Asa Ekdahl	world steel association	Belgium
25225	28	36	28	36	Replace "than" with "then"	Noted thank you	Eleni Kaditi	Organization of the Petroleum Exporting Countries (OPEC)	Austria
13273	28	37	28	41	HYBRIT is a join venture between LKAB, SSAB and Vattenfall. ArcelormIttal, salzgitter and voestalpine have similar projects while TKS is injecting H2 in the BF	Hydrogen box needs to be rewritten. Thank you, points taken, we will attempt to include this.	Asa Ekdahl	world steel association	Belgium
29147	29	1	29	1	Please add the definition of biogenic carbon in the glossary	Accepted	Minal Pathak	Ahmedabad University	India
28015	29	1	29	10	CCUS in industry is an opportunity cost. It reduces only CO2. The same money used for the CCUS equipment and energy should be used instead to replace coal, gas, or oil fossil plants with wind, water, or solar power and reduce more CO2 while also reducing 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. Thus, there is no situation where using CCS/U for industry is better than spending the same equipment and energy money simply on replacing fossil fuels. Please clarify this.	CCUS in industry, including with biogenic carbon is not in conflict with RE investments. The reference is about coal vs. Wind. We will be clear about what we mean with CCU	Mark Jacobson	Stanford University	United States of America
20485	29	1	29	46	the high CCU potential, also using DACCU is highlighted in 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), while the the cement CCU potential is discussed in detail in Farfan et al. (https://www.sciencedirect.com/science/article/pii/S0959652619302185)	We will consider adding those references	Christian Breyer	LUT University	Finland
39007	29	4	29	4	The definition of CCUS is absolutely incorrect. Here CCUS should be replaced by CCU!	Will revise	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
29127	29	5	29	5	In line with the glossary definition, might it be more appropriate to say use of 'carbon either as feedstock or stored in a product'	Will revise aligned with other CCUS comments	Minal Pathak	Ahmedabad University	India
39009	29	7	29	7	Please replace CCUS by CCS here!	We will clarify and make distinction between CCU and CCS	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
36789	29	7	29	10	the reference of CO2 prices is not justified. Recent report of IEAGHG (https://ieaghg.org/exco_docs/2017-TR3.pdf and https://ieaghg.org/exco_docs/2017-02.pdf) for different H2 production plant layouts integrated with CCS are ranging from 47-70 eur/tCO2	Will revise	Vincenzo Spallina	University of Manchester	United Kingdom (of Great Britain and Northern Ireland)
37563	29	8	29	8	The literature source where the CO2 price range is taken should be referred to.	Yes, and there are other estiamtes as well, see comment 361	Michiel Schaeffer	Climate Analytics	Netherlands
39011	29	8	29	8	Please replace CCUS by CCS here!	This is a key challenge for both CCU and CCS. Will clarify	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
44829	29	10	29	10	"Industrial clustering" is especially difficult in EU	Thanks, will be revised	Véronique Waroux	Planète-A	Belgium
13275	29	11	29	12	Surely the goal must be that no CO2 from fossil sources is emitted to the atmosphere!	We will rephrase	Asa Ekdahl	world steel association	Belgium

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18039	29	11	29	14	Disagree with this generalisation. It is possible to capture 99.7% of CO2 from some industrial plant where the CO2 emissions are in the flue gas, see Feron (2019) Int Journal Greenhouse Gas Control V87 p188-202 and IEAGHG report 2019-02	same comment as below	Tim Dixon	IEAGHG	United Kingdom (of Great Britain and Northern Ireland)
30907	29	11	29	14	For (industrial) combustion related flue gases, >99% CO2 capture rates can be achieved, see Feron (2019) Int Journal Greenhouse Gas Control 87 p.188-202 and IEAGHG report 2019-02.	We will clarify and make distinction.	Jasmin Kemper	IEA Greenhouse Gas R&D Programme (IEAGHG)	United Kingdom (of Great Britain and Northern Ireland)
23037	29	11	29	20	I appreciate the acknowledgement of the importance of life cycle assessment (not cost analysis) for the determination of sensibility of CCU. It would be good to have a number of papers cited. Their insights can help evaluate the technology. As an example, Dominguez-Rames et al (10.1016/j.jclepro.2013.11.046) investigated the production of formic acid from captured CO2 and found that it was more polluting than the conventional route of producing it from natural gas. Still, technology development continues to be funded, which really makes no sense. It would be nice if the section could tell use what CCU routes are good prospects and how far away we are from a potential commercialization of the technologies. This is more approriate here than in the energy chapter.	The section on CCU and CCS will be revised in light of this and many other comments	Edgar Hertwich	Norwegian University of Science and Technology	Norway
39013	29	11	29	20	This paragraph discusses the utilisation, so please replace both CCUS terms by CCU. This paragraph lacks references. Here are key statements from the recent literature on this subject: The study of Sternberg et al., 2017 shows that the CO2-based production of formic acid can reduce environmental impacts compared to the fossil-based process even if hydrogen is supplied by fossil-based steam-methane-reforming. Aldaco et al., 2019 suggest that electrochemical reduction of CO2 to produce formic acid can be less emission intensive (about 35% life cycle CO2 savings) than conventional production from 2030 onwards, assuming a defosilization of the energy system consistent with the Paris Agreement. In a comprehensive analysis of LCA from CO2-based chemical production, Thonemann, 2019 reports emission reductions up to 420% compared to conventional production for renewable electricity-based chemicals like methanol, DME, formic acid and polyols. Ampelli et al., 2015 underline the strategic role of CO2-to-chemicals pathways as a way of progressively introducing more renewable energy into chemical value chains, thus helping the reduce dependencies from fossil fuels both as carbon feedstock and as energy source. Fernandez-Dacost et al., 2017 report CO2-eq emission reductions of about 23% between conventional and CO2-based polyol production. Kätelhön et al., 2019 suggest that the climate change mitigation potential of CCU in the chemical industry will not be dependent on the amount of CO2 used in the process, but on the potential for substitution of conventional products. From an LCA perspective, they cover the 20 most greenhouse gas intensive chemicals in Europe and conclude that the technical mitigation potential of CO2-based chemical production (i.e. technically feasible GHG reductions under full deployment of technologies) can be up to 3.5 Gt CO2-eq by 2030; The technologies are already available to switch to CO2 and water as substrates, but this would require massive amounts of renewable electricity. Thonemann and Pizzol., 2019 conducted a consequential LCA for various CCU products in the chemical industry and concluded that formic acid produced via hydrogenation and polyol production are the conversion technologies with the highest potential for reducing the global warming impact from a life cycle perspective. Interestingly, they claim that for long-term scenarios where CO2 demand will increase and will be covered from dilute sources, the global warming potential of CCU will increase due to higher intensities related to capture. Therefore, they suggest not to postpone CCU technologies deployment for later. The estimated utilization potential for CO2 in chemicals is around 0.3 to 0.6 Gt CO2 yr−1 in 2050, and the interquartile range of breakeven costs obtained from the scoping review is −$80 to $320 per tonne of CO2. Currently, the largest-scale chemical utilization pathway is that of urea production. 140 Mt CO2 yr−1 is utilized to produce 200 Mt yr−1 of urea (Hepburn et al, 2019). For the production of polymers, the utilization potential of CO2 is estimated to be 10 to 50 Mt yr−1 in 2050. In the current market structure, around 60% of plastics have applications in sectors other than packaging— including as durable materials for construction, household goods, electronics, and in vehicles. Such products have lifespans of decades or even centuries (Geyer et al, 2017, Hepburn et al., 2019).(REFERENCES: Geyer et al., 2017: Production, use, and fate of all plastics ever made. Sci. Adv. 3/ 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/ Aldaco et al., 2019, Science of the Total Environment, 663, 738-753./ Hepburn et al., 2019: The technological and economic prospects for CO2 utilization and removal, 575, 87-97./Thonemann, 2019, Applied Energy, 263, 114599./ Sternberg et al., 2017, Green Chemistry, 9./Fernandez-Dacost et al., 2017, J. CO2. Util., 21, 405-422./ Thonemann and Pizzol., 2019, Energy Environ. Sci., 12, 2253./Kätelhön et al., 2019: Climate change mitigation potential of carbon capture and utilization in the chemical industry, PNAS, 116, 23, 11187-11194.	Good comments and the section will be revised accordingly, but we have to be careful about space and cannot include all detail.	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
39015	29	26	29	26	This should be added: 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. 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, IEAGHG, 2019a, GCI, 2016). (Hepburn et al., 2019: The technological and economic prospects for CO2 utilization and removal, 575, 87-97./• Zhu, 2019, Clean Energy, Vol. 3, No. 2, 85–100./ IEAGHG, 2019a: Putting CO2 to Use – Creating value from emissions, International Energy Agency./ GCI, 2016: Global Roadmap Study of CO2U Technologies, LUX Research & Global CO2 Initiative/IEAGHG, 2019b: Exploring Clean Energy Pathways: the role of energy storage, International Energy Agency../ Bruhn et al., 2016, Environmental Science & Policy, 60, 38–43./Kätelhön et al., 2019: Climate change mitigation potential of carbon capture and utilization in the chemical industry, PNAS, 116, 23, 11187-11194./Nocito and Dibenedetto, 2020, Current Opinion in Green and Sustainable Chemistry, 21, 34–43./ Arning et al. 2019, Energy Policy, 125, 235–249.)	The section will be revised taking into account this and other comments from Sapart	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
23035	29	1	30	2	The text here is too generic and too little about recent progress. There is an overalp with section 11.3.5. I suggest that feedstocks and biogenic carbon should be included there and this section should focus on CCUS.	The sections will be revised to separate between CCU and CCS and biogenic CCU and CCS.	Edgar Hertwich	Norwegian University of Science and Technology	Norway

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33023	29	1	30	2	See comment 12, but this is repeating some of the information in the previous section - it needs to be more clearly organised. Also important to note the overlapping of some of the subsets of options - is an SMR/ATR/NH3/MeOH facility fitted with CCUS 'hydrogen' or 'CCUS', or both?	Good observation about overlap. Yes it is both.	Peter Levi	International Energy Agency	France
37565	29	1	30	2	There is recent literature looking into sustainable potential of biomass in different world regions for application in energy sector. Referring to those literature and citing the quantitative estimates already available would be quite useful to mention here than pure qualitative statements.	We will not elaborate on this in Ch 11 but refer to Ch 7 and 12 as well as upcoming Box on Biomass	Michiel Schaeffer	Climate Analytics	Netherlands
46113	29	1	30	2	CCU report by SAPEA should be mention. https://www.sapea.info/topics/carboncaptureandutilisation/	The report will be cited if it contains information that adds to the section	Neven Duic	University of Zagreb	Croatia
9627	29	1			It would be helpful to compare the total mass of carbon used annually in some large volume commodities (e.g. non-fuel hydrocarbons, plastic production) to the mass of carbon currently emitted as CO2 per year. Some scientific communities seem to view CCUS as a panacea, but the huge difference between these two numbers illustrates that at best it can only be a small fraction of the "solution".	This is a good point and we will try to find literature and numbers on this	David Sholl	Georgia Institute of Technology	United States of America
40275	30	1	30	3	unclear how sentence 1 and sentence 2 would contribute to sentence 3	It is unclear what sentences the comment refers to but 11.3.6 will be revised and improved for clarity	Vida Rozite	International Energy Agency	France
38537	30	6	30	16	In the first 2 sentences, you refer to 4 reports: Bataille et al. (2018c); Material Economics (2019b); IEA (2019b); Energy Transitions Commission (2018a), then in the sentence starting on line 12 you say "The key conclusion is…" but then you cite only one of the same reports (Material Economics 2019) as well as a different report (UKCCC 2019b). Thus, I don't think you are characterizing the key conclusions of the first 4 reports, so this needs to be reworded. But, why don't you include the Bataille, IEA, and ETC report conclusions also?	Accepted	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
9757	30	12	30	16	The possibility of Net-zero emissions from indusrial sector in Korea. It is expected that Korea will not achieve carbon neutral by 2050 in the industrial sector even with all available means of reduction, and it is discussed that carbon neutral requires innovative means and extensive government support. Major reduction measures such as hydrogen technology and CCUS are expected to have limited reduction effects due to the early stages of research and development, the late commercialization period, and resistance to huge cost requirements.	Thank you. Agree	JAE YOON LEE	Korea Institute for Industrial Economics and Trade(KIET)	Republic of Korea
38509	30	15	30	16	I think this sentence is a bit of a value judgment, so I would remove it. Deploying the multiple options could be technically feasible, but what about the costs and what about already built assets that would either need to be retired early or retrofit. I just think that the information provided above (which could be supplemented with some discussion of the costs of these options) is sufficient for the reader to determine whether these sectors are still hard-to-abate compared to other sectors.	Accepted	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
39017	30	17	30	20	Here it states that "all technological options have to be mobilized", but this is not what is reflected in the discussion as e.g. a proper and updated discussion on CCU is missing even though this fast growing concept might be the most promising concept to defosilized the intensive industry. "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). (Zhu, 2019, Clean Energy, Vol. 3, No. 2, 85–100.Hepburn et al., 2019: The technological and economic prospects for CO2 utilization and removal, 575, 87-97.)	Accepted. CCU discussion sharpened	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
17109	30	21	30	22	Not clear to what the % refer. E.g. should they be read vertically or horizontally?	Thanks	Kornelis Blok	Delft University of Technology	Netherlands
38539	30	21	30	23	This table relies on only one report that is focused on the material efficiency issue. I suggest that you include information from some of the other reports that are cited in this section.	Reject. Not possible. Several sources are there for the C&P table	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
38515	30	21	30	26	I don't see any changes in this table since the internal draft. I had been waiting for the promised improvements, but now I will provide my comments. First, the table title needs to indicate that this is just for the EU. The "Contribution to emission reduction (%)" needs to be explained - what are the baseline vs deep decarbonization assumptions? For what year are these reductions? Is this global? For Europe? Regarding for example the steel industry, the energy efficiency potential of 5-23% is for BF-BOF (primary) steel making, EAF (secondary) steel making, or all steel making combined? What does "Fossil fuels and waste fuels" mean? For the growth of electricity demand compared with 2015, for what year is this? What are the investment needs assumptions - new facilities, retrofits? Under what conditions do these costs of production go up? Presumably energy efficiency will lower costs. If there is a price on CO2, then many of these options could lower costs or break even.	Moved to 11.4 and revised	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
36379	30	4	32	29	Please see the comment No.1 and No. 3	Noted.	Shigetaka Seki	Consumer Product Safery Association	Japan
44831	30	5	32	29	Please note that for cement, the proposed measures apply to percentages of CO2 emissions (e.g. biomass on the 40% combustion, electricity on the grinding, circularity on the 60% decomposition of limestone, etc.). The ideas may be correct but the proportions should be checked according to the point of application.	Thanks	Véronique Waroux	Planète-A	Belgium
44833	30	5	32	29	As regards the trend in cement consumption, the geopolitical context is an element which may be significant (e.g. construction of partition walls) but which is not taken into account. Geopolitical uncertainty can be pointed out.	Reject too specific	Véronique Waroux	Planète-A	Belgium
44835	30	5	32	29	The health aspect is not taken into account. When reusing, care must be taken not to add harmful materials.	Agree	Véronique Waroux	Planète-A	Belgium
26261	30	5			The section is a bit confusing and keeps reciting the same two references (IEA 2019b and Material Economics 2019b)	Revised	Sara Budinis	International Energy Agency	France
20697	30	10			There is only one reference from Material Economics in 2019. Suggest to replace the year of reference from 2019b to 2019.	Thanks	JUNGYU PARK	International Energy Agency	France

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
26243	30	20			What about : Carbon capture, utilisation and storage; investments into best available technologies?	We distinguih between CCU and CCS not to mix them up, due to many other comments	Sara Budinis	International Energy Agency	France
26245	30	20			What does circularity refers to? Material efficiency or what? Please explain	Revised and also make reference to Ch5	Sara Budinis	International Energy Agency	France
26247	30	20			what is end of life plastic? Pelase explain	Reject. Obvious	Sara Budinis	International Energy Agency	France
23039	30	21			Please note this table is also contained in Chapter 5. Please coordinate.	Yes, thanks	Edgar Hertwich	Norwegian University of Science and Technology	Norway
26249	31	3	7		Many numbers, little explanation, almost zero references	Revised	Sara Budinis	International Energy Agency	France
26251	31	8	12		very confusing, please rephrase	Revised	Sara Budinis	International Energy Agency	France
26253	31	16	17		why half of currently consumed materials? Please explain and add one or multiple references on where this estiamate comes from	Revised	Sara Budinis	International Energy Agency	France
38649	31	1	31	1	Earlier comment that wasn't addressed: I am not sure how Figure 11.2 supports this statement. Please clarify. Additional comment now - given my detailed comments on this figure (above), I think that it is difficult to make such a summary statement. Please be more scientific and accurate. The figure shows large energy savings potential for the steel industry, for example. The figure doesn't even provide information to draw any conclusions from for the copper industry.	Nuance added but the point remains that EE will not be enough for zero emissions	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
38517	31	1	31	7	Earlier comment that wasn't addressed: I find this paragraph contains statements that don't align well. First: "Energy saving potential in materials manufacture is not exhausted, yet still limited" and then: "This limits the potential energy efficiency contribution to 2-23% in different pathways towards a carbon neutral industry" and then: "In scenarios leaving 40-50% industrial emissions unabated by 2050-2060 energy efficiency still dominates contributing with 46% cumulative CO2 emissions reductions." It is unclear what the message is here - please clarify. New comment: The statement "This limits the potential energy efficiency contribution to 2–23% in different pathways towards a carbon neutral industry on the background of material efficiency and circularity contribution ranging 5–44% (Table 11.2)." is based on only one study. To make such a definitive and broad statement, I would expect you to cite more literature here.	Section extensively revised to clarify	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
29065	31	16	31	17	Several instances of prescriptive language in the chapter	Accepted	Priyadarshi Shukla	Ahmedabad University	India
29129	31	16	31	17	Please check: prescriptive language	Yes, thanks	Minal Pathak	Ahmedabad University	India
40233	31	17	31	17	"consumed materials" instead of "consumed physical materials". The concept physical materials is not used	Thanks, accepted	Ana Ines Fernandez	University of Barcelona	Spain
39019	31	43	31	43	Please rephrase: Therefore, zero-emission electricity, hydrogen, captured and converted CO2 and biomass use as fuel and feedstock are becoming key drivers for deep decarbonization in the industrial sector.	Accepted	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
38519	31	44	31	45	The BOF does not use much energy, so I think you might be referring to the BF? You could say the BF/BOF process, but not the BOF process alone.	Yes, thanks	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
38523	31	45	31	45	Earlier comment that wasn't addressed: First sentence needs a reference. Please provide the reader with the share of global steel produced by the EU. The global share of steel produced by the EU is important because the ME potential estimate may only apply to that market, so it would be informative for the reader to know its size.	Section revised and shortened not to have sector specific numbers	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
38521	31	45	31	46	Since the previous statement of 15% energy efficiency improvement is incorrect and since figure 11.9 shows about a 50% energy efficiency potential for crude steel (from ~20 GJ/t 2017 to ~10 GJ/t BAT), you can't then say "potential ME contribution for EU is much higher - 48%". If it is possible to compare these two values (depends on the assumptions of the ME study), then I would say that the potential ME contribution is similar to the contribution from energy efficiency.	Section now heavily revised to exclude sectotal detail	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
33025	31	8	32	29	Again, it feels like there is repitiion here - can you deal with all of the material efficiency/demand reduction etc. in one section, rather than going back and forth? It's very hard to follow and get a sense of the main options in one go at the moment.	Thanks. This should be clear throughout the chapter	Peter Levi	International Energy Agency	France
38525	31	46	32	2	By using the term "recycling" do you mean producing steel using scrap metal in an electric arc furnace? If so, then you should state this.	Accepted. Caveats added where appropriate	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
8935	32	1	32	2	See also Morfeldt et al. (2015). Secondary steel production is limited since it alone won't be able to cover future demand, even when saturation of the in-use steel stock is taken into account and demand is adjusted when saturation occurs. Morfeldt, J., Nijs, W., & Silveira, S. (2015). The impact of climate targets on future steel production – an analysis based on a global energy system model. Journal of Cleaner Production, 103, 469–482. https://doi.org/10.1016/j.jclepro.2014.04.045	Reject. Too detailed for this section	Johannes Morfeldt	Chalmers University of Technology	Sweden
14287	32	3	32	3	Addition: "Steel production waste fractions (e.g. steel slag) carbonated with CO2 from industrial emissions can also lead to significant GHG emission reductions. Pan et al., 2017 estimate that the amount of worldwide reduction by CO2 mineralization using iron and steel slags was approximately 137.5 Mt per year, contributing to a reduction of the global anthropogenic CO2 emissions by 0.38% (https://doi.org/10.1038/s41598-017-17648-9). Mattila et al (2017) report that steel slag-based precipitated calcium carbonate leads to negative emissions and replacement of the traditional PCC would lead to more than twofold GHG emission reductions (http://dx.doi.org/10.1016/j.jclepro.2014.05.064). Di Maria et al (2020) conducted an LCA of carbonated steel slag including CO2 capture and confirm that mineral carbonation is a negative-carbon-footprint technology; compared to Portland cement concrete blocks, GHG emission reductions of up to 77% were reported (https://doi.org/10.1016/j.ijggc.2019.102882)"	Reject. Too detailed for this section	Anastasios Perimenis	CO2 Value Europe (Association) - CCU Offiver	Belgium

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
14289	32	3	32	3	Addition suite: "Kirchoffer et al (2013) claim that carbonation of fly ash, cement kiln dust and steel slag has a combined potential to mitigate around 7.5 MtCO2/a, of which 7 MtCO2 through the mineralization process itself and 0.5 through the replacement of the mined aggregate with synthetic waste-based aggregate (https://doi.org/10.1016/j.egypro.2013.06.510). Lee et al (2020) suggest that the production of calcium carbonate from carbonation of steel slag instead of limestone can lead to net GHG savings of up to 1.5 MtCO2/a globally (https://doi.org/10.1016/j.jcou.2019.12.005)"	Section revised and such detail provided in sectoral section in 11.4	Anastasios Perimenis	CO2 Value Europe (Association) - CCU Offiver	Belgium
38527	32	3	32	3	The last sentence needs a reference and it would be helpful if you could provide some indication of the magnitude of "some of the coal input". Is it 5%, 50%? This makes a difference.	Thanks	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
8845	32	8	32	8	This paper: doi.org/10.1016/j.energy.2011.05.019 quantifies the potential of Best Available Technologies to improve energy efficiency in the chemical and petrochemical sectors of selected countries as well as worldwide, with a total quantified potential of 16% (excluding electricity savings).	accept	Saygın Değer	SHURA Energy Transition Center	Turkey
38529	32	8	32	19	Can you also provide the IEA 2019b findings for these two sectors?	Thanks	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
11865	32	15	32	15	Isn't it better to use "21st century", rather than "XXI century"?	Thanks. Sectoral detail will be in 11.4	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
14291	32	15	32	15	Addition: "Aldaco et al., 2019 suggest that electrochemical reduction of CO2 to produce formic acid can be less emission intensive (about 35% life cycle CO2 savings) than conventional production from 2030 onwards, assuming a decarbonization of the energy system consistent with the Paris Agreement (https://doi.org/10.1016/j.scitotenv.2019.01.395). In a comprehensive analysis of LCA from CO2-based chemical production, Thonemann 2020 reports emission reductions up to 420% compared to conventional production for renewable electricity-based chemicals like methanol, DME, formic acid and polyols (https://doi.org/10.1016/j.apenergy.2020.114599). Fernandez-Dacost et al., 2017 report CO2-eq emission reductions of about 23% between conventional and CO2-based polyol production (http://dx.doi.org/10.1016/j.jcou.2017.08.005). "	See previous response	Anastasios Perimenis	CO2 Value Europe (Association) - CCU Offiver	Belgium
14293	32	15	32	15	Addition suite: "Thonemann and Pizzol, 2019 conducted a consequential LCA for various CCU products in the chemical industry and concluded that formic acid produced via hydrogenation and polyol production are the conversion technologies with the highest potential for reducing the global warming impact from a life cycle perspective (https://doi.org/10.1016/j.apenergy.2020.114599). Kätelhön et al., 2019 conduct an LCA covering the 20 most GHG intensive chemicals in Europe and conclude that the technical mitigation potential of CO2-based chemical production (i.e. technically feasible GHG reductions under full deployment of technologies) can be up to 3.5 Gt CO2-eq by 2030 (https://doi.org/10.1073/pnas.1821029116)"	Thanks. Cement discussion in 11.4 now	Anastasios Perimenis	CO2 Value Europe (Association) - CCU Offiver	Belgium
38531	32	16	32	17	This is a widely studied option - I'm not sure why you are citing only this one study. The whole cement discussion could be improved - you need to explain how there are both energy and process emissions and which options can reduce which emissions (and by how much).	See previous response	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
2221	32	16	32	19	Add in line 18 the following phrase: "Sanjuán et al (2016) have assessed the CO2 emission reduction potential in the cement sector. The main sources of CO2 emissions were considered. Measures having both a high applicability and a high technological maturity were selected as possible options to prioritize. In particular, clinker substitution has both characteristics: a high applicability and a high technological maturity. Therefore, it is feasible from a technological and economic perspective. The clinker substitution rate constantly increased during the last decade. However, there is still a considerable potential for improvement. In Europe, 719 kg CO2 per ton of cement was emitted in 1990, 695 kg CO2 per ton of cement in 2000 and, currently, 627 kg CO2 per ton of cement (2013). On the other hand, in the United States this value remains in 737 kg CO2 per ton of cement. Reference: M. A. Sanjuán; E. Menéndez; C. Argiz; A. Moragues. Coal bottom ash research program focused to evaluate a potential Portland cement constituent. II International Conference on Concrete Sustainability, ICCS16. Madrid, 13-15 June, 2016. CIMNE Ed. 532-543. ISBN: 978-84-945077-7-9. https://www.rilem.net/global/gene/link.php?doc_link=/media/event/2015112606_ICCS16Madridflyer032015b.pdf	See previous response	Miguel Angel Sanjuán	Technical University of Madrid	Spain
2223	32	16	32	19	Add after the line 19 the Figure 3 from the reference: M. A. Sanjuán; E. Menéndez; C. Argiz; A. Moragues. Coal bottom ash research program focused to evaluate a potential Portland cement constituent. II International Conference on Concrete Sustainability, ICCS16. Madrid, 13-15 June, 2016. CIMNE Ed. 532-543. ISBN: 978-84-945077-7-9. https://www.rilem.net/global/gene/link.php?doc_link=/media/event/2015112606_ICCS16Madridflyer032015b.pdf Figure 3: Results of the assessment for CO2 emissions reduction potential - implementation maturity and technical applicability.	See previous response	Miguel Angel Sanjuán	Technical University of Madrid	Spain
8937	32	16	32	19	Switching fuels to biomass will not result in deep decarbonisation since the process emissions from the calcination of limestone persist. Therefore it should be stated as "... and equiping cement produciton facilities with CCS".	See previous response	Johannes Morfeldt	Chalmers University of Technology	Sweden
12541	32	16	32	19	Add in line 18 the following phrase: "Sanjuán et al (2016) have assessed the CO2 emission reduction potential in the cement sector. The main sources of CO2 emissions were considered. Measures having both a high applicability and a high technological maturity were selected as possible options to prioritize. In particular, clinker substitution has both characteristics: a high applicability and a high technological maturity. Therefore, it is feasible from a technological and economic perspective. The clinker substitution rate constantly increased during the last decade. However, there is still a considerable potential for improvement. In Europe, 719 kg CO2 per ton of cement was emitted in 1990, 695 kg CO2 per ton of cement in 2000 and, currently, 627 kg CO2 per ton of cement (2013). On the other hand, in the United States this value remains in 737 kg CO2 per ton of cement. Reference: M. A. Sanjuán; E. Menéndez; C. Argiz; A. Moragues. Coal bottom ash research program focused to evaluate a potential Portland cement constituent. II International Conference on Concrete Sustainability, ICCS16. Madrid, 13-15 June, 2016. CIMNE Ed. 532-543. ISBN: 978-84-945077-7-9. https://www.rilem.net/global/gene/link.php?doc_link=/media/event/2015112606_ICCS16Madridflyer032015b.pdf	See previous response	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
12543	32	16	32	19	Add after the line 19 the Figure 3 from the reference: M. A. Sanjuán; E. Menéndez; C. Argiz; A. Moragues. Coal bottom ash research program focused to evaluate a potential Portland cement constituent. II International Conference on Concrete Sustainability, ICCS16. Madrid, 13-15 June, 2016. CIMNE Ed. 532-543. ISBN: 978-84-945077-7-9. https://www.rilem.net/global/gene/link.php?doc_link=/media/event/2015112606_ICCS16Madridflyer032015b.pdf Figure 3: Results of the assessment for CO2 emissions reduction potential - implementation maturity and technical applicability.	See previous response	MORA PERIS PEDRO	Profesor Titular de Universidad de la ETSI Minas y Energía de la Universidad Politécnica de Madrid	Spain
27481	32	16	32	19	The text needs to include a reference to the emerging trend where waste is increasingly being used as an alternative to conventional fossil fuels in cement kilns worldwide. This has led to the emergence of socio-environmental conflicts in many countries in which local groups articulate a common struggle against the cement industry, a new target within the international anti-incineration movement. Herrero, Amaranta, and Mariel Vilella. "'We have a right to breathe clean air': the emerging environmental justice movement against waste incineration in cement kilns in Spain." Sustainability Science 13.3 (2018): 721-731.	See previous response	Mariel Vilella Casaus	Zero Waste Europe	United Kingdom (of Great Britain and Northern Ireland)
14295	32	19	32	19	Addition: "Kaliyavaradhan and Ling (2017) estimate that 270 kg of CO2 can be sequestered if 1 t of waste cement is completely carbonated (http://dx.doi.org/10.1016/j.jcou.2017.05.014). Lim et al. (2019) suggest that up to 1,1 GtCO2 per year of emissions from the concrete industry globally could be mitigated by incorporating CO2 in concrete mixing or in recycled concrete aggregates (https://doi.org/10.1088/1748-9326/ab466e). Chen et al (2016) report that replacing 10% of Portland cement clinker by carbonated basic oxygen furnace slag (produced via high gravity carbonation) can lead to reductions of up to 120 kgCO2/t_blended_cement directly from the carbonation process and indirectly from the avoidance of clinker production (http://dx.doi.org/10.1016/j.jclepro.2016.02.072)"	See previous response	Anastasios Perimenis	CO2 Value Europe (Association) - CCU Offiver	Belgium
14297	32	19	32	19	Addition suite: "Zhang et al (2020) calculate that concrete debris has the potential to mitigate, at global scale about 62.5 MtCO2 under optimal carbonation conditions determined by pressure, temperature, humidity, time, CO2 concentration, and debris size. Their scenario analysis indicate that the global cumulative carbonation of concrete debris could be as high as 3.0 GtCO2 between 2018 and 2035 (https://doi.org/10.1016/j.rser.2019.109495). Huang et al (2019) report a GWP of 292 kgCO2-eq/m3 of concrete block for a CO2-cured wollastonite-based cement, which corresponds to approximately 30% life cycle GWP reduction compared to a conventional steam-cured ordinary cement. Adding the CO2 capture and transport processes would mean that the GWP reduction is in the order of 18% (https://doi.org/10.1016/j.jclepro.2019.118359). Pasquier et al (2018) claim that the GHG Balance of waste concrete carbonation is positive with a net reduction of 10kgCO2/t of waste concrete (https://doi.org/10.3390/geosciences8090342)"	See previous response	Anastasios Perimenis	CO2 Value Europe (Association) - CCU Offiver	Belgium
45401	32	19	32	19	Refer to the results from CEMCAP project. You can refer to two publication from the project: 1. Comparison of Technologies for CO2 Capture from Cement Production—Part 1: Technical Evaluation 2. Comparison of Technologies for CO2 Capture from Cement Production—Part 2: Cost Analysis	See previous response	Shareq Mohd Nazir	KTH Royal Institute of Technology	Sweden
2623	32	23	32	23	…"production of aluminium (PFCs)." should read "production of aluminium and rare earth metals (PFCs). In both cases, the use of non-carbon electrodes in the smelting process offers a potential pathway to PFC-emission-free production, see page 11-42 lines 26-31. In the case of semiconductor manufacture, the use of PFC-alternative gases and exhaust gas abatement have already reduced PFC emissions by >90%."	Thanks. Considerer in 11.4	Michael Czerniak	Atlas Copco - Edwards	United Kingdom (of Great Britain and Northern Ireland)
8847	32	31	32	31	This paper: doi.org/10.1016/j.enpol.2013.09.025 quantifies an average CO2 mitigation cost of improving energy efficiency for 2030 at US$20 per tonne CO2 avoided based on the implementation of best practice technologies in the global steam cracking process, ammonia production and methanol production.	Thanks, accepted but elaborated in other sections	Saygın Değer	SHURA Energy Transition Center	Turkey
38541	32	31	33	46	In the first paragraph of this section, you cite 3 IEA reports, but the findings from these reports are then never referred to in the rest of this section. IEA 2019b, for example, finds "Material efficiency does not come without challenges and costs. Real and perceived risks, costs, time constraints, fragmented supply chains, regulatory restrictions and lack of awareness are some of the many barriers to greater uptake of material efficiency strategies. Improving material efficiency will in many cases incur costs, although estimates suggest that these may fall within a reasonable range compared to other emissions mitigations options." This is directly relevant to the discussion of mitigation costs.	Thanks, accepted but elaborated in other sections	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
38533	32	46	33	5	please provide costs in US$ (not pounds).	Noted thank you, we will standardise	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
44837	33	5	33	5	Check if "limited" is the correct word	Noted	Véronique Waroux	Planète-A	Belgium
45403	33	6	33	19	It would be nice to consider consistency in the units for costs. Using 3 different units, euro, dollar and GBP might confuse the reader. May be do the same for the whole capter if it is needed.	Noted thank you, we will standardise	Shareq Mohd Nazir	KTH Royal Institute of Technology	Sweden
13277	33	22	33	22	the cost estimates for making low carbon steel seems low. HYBRIT in Sweden estimates 30% increased cost and they have all the best pre-conditions. We believe that for most steel makers it is likely to be much higher, up to 100%	Thanks. Cost discussion moved elsewhere and nuanced	Asa Ekdahl	world steel association	Belgium
13279	33	31	33	32	This is similar fo the other materials and when you add iot all up the additional cost on a car or a house might not be so insignificant	Accepted. Language nuanced	Asa Ekdahl	world steel association	Belgium
13281	33	31	33	36	An increased cost for production of 20% or (much) more for a steel producer with already low margins, competing globally. Unless carbon free steel would be priced at a premium on the market the first movers are likely to go out of business.	Accepted.	Asa Ekdahl	world steel association	Belgium
38535	33	37	33	37	Which sectors are referred to ("in these sectors")?	11.3.7 now heavily revised	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
11867	33	40	33	41	Either "global" or "globally" can be deleted in this sentence.	Thanks	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
38543	34	16	34	20	This table only presents the results of four IEA scenarios from two reports. It would be very interesting to also include the results from the other key reports that you cite throughout this chapter and to divide the findings into the key contributing components (e.g. energy efficiency, materials efficiency, electrification, etc.). If this is done, it would be a great achievement in terms of the mandate of the IPCC - to review the current literature and provide an assessment. It would allow the reader to compare the assumptions and findings of all of the most recent reports. I encourage you to undertake such an effort.	We will attempt to do so	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
44839	35	29	35	32	"structural and mind-set changes": This paragraph should be further developed in Chapter 11.	Text will be revised and consolidated with text in other sections	Véronique Waroux	Planète-A	Belgium

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
44841	35	46	35	46	R&D should be further developed, even in the introduction to point 11.4. R&D is discussed only from page 64 onwards.	Rejected: R&D needs will be discussed in later parts of the text, introduction should give an overview of the text that follows and is not meant to summarize key findings	Véronique Waroux	Planète-A	Belgium
28715	36	7	36	7	I think it is very important reiterate that for integrated steelmaking process, the reduction potential for specific energy use / CO2 emissions per t-crude steel is limited (esp. when Paris climate goals are considered) even with best available technologies. A few references that can be added here: Moya, J.A., Pardo, N., 2013. The potential for improvements in energy efficiency and CO2 emissions in the EU27 iron and steel industry under different payback periods. J. Clean. Prod. 52, 71–83. Pardo, N., Moya, J.A., 2013. Prospective scenarios on energy efficiency and CO2 emissions in the European Iron & Steel industry. Energy 54, 113–128. Arens, M., Worrell, E., Eichhammer, W., Hasanbeigi, A., Zhang, Q., 2016. Pathways to a low-carbon iron and steel industry in the medium-term - the case of Germany. J. Clean. Prod. 1–15. https://doi.org/10.1016/j.jclepro.2015.12.097 Hasanbeigi, A., Morrow, W., Sathaye, J., Masanet, E., Xu, T., 2013. A bottom-up model to estimate the energy efficiency improvement and CO2 emission reduction potentials in the Chinese iron and steel industry. Energy 50, 315–325. https://doi.org/10.1016/j.energy.2012.10.062 Kuramochi, T., 2016. Assessment of midterm CO2 emissions reduction potential in the iron and steel industry: a case of Japan. J. Clean. Prod. 132, 81-97. https://doi.org/10.1016/j.jclepro.2015.02.055	Accepted thank you these will be considered	Takeshi Kuramochi	NewClimate Institute	Germany
13283	36	8	36	10	Strangely formulated sentence. Better refer to worldsteel.org In 2018: building and infrastructure 51%, metal products 11%, electrical equipment 3%, mechanical equipment 15%, Automotive 12%, domestic appliances 3% , other transport 5%	Accepted	Asa Ekdahl	world steel association	Belgium
13285	36	14	36	18	Add that steel scrap is used in both routes(up to 30% in the BOF) and that both routes can produce the same qualities/products	Accepted	Asa Ekdahl	world steel association	Belgium
38545	36	20	36	21	Do you really mean to say that "each" of the "several options" could reduce CO2 emissions of primary steel production by 80%? I don't think so - please double-check this.	Review, but I don't think she is correct.	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
38547	36	22	36	22	I believe it should be "dominant blast furnace/basic oxygen furnace route" (these are two different pieces of technology).	Yes, but they are used together.	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
38549	36	22	36	22	What is meant by "if input streams are based on carbon-free energy sources"? Do you mean to replace all fossil-fuel inputs and have carbon-free electricity? Then the statement above would be 100%, not 80%. But is the full use of carbon-free energy sources realistic?	We will clarify thank you	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
13287	36	23	36	26	There is a contradiction in this sentence. As stated in the end, the scope is limited since 85% is already recycled!	OK	Asa Ekdahl	world steel association	Belgium
8693	36	23	36	31	- There are three types of iron scrap: internal scrap (which is produced during steel production processes), manufacturing scrap (which is produced during production processes for industrial products, etc.), and end-of-life scrap (which is produced from the accumulation of steel). The amount of production of internal scrap is proportional to the amount of production of steel, and the amount of production of manufacturing scrap is proportional to the amount of shipment of steel. The amount of production of end-of-life scrap tends to change by a constant fraction of the amount of accumulation of steel (see the Japan Iron and Steel Federation's long-term vision). Therefore, it should be noted that if steel demand declines (i.e., there are declines in production or shipment of steel), and the amount of accumulation of steel in society does not expand, then the amount of production of scrap will also decline.	OK	HIROYUKI TEZUKA	JFE Steel Corporation	Japan
9759	36	23	36	31	Due to the nature of the Korean steel industry, which has an absolutely high proportion of BOF production, the key is to develop technologies that can make the quality of crude steel from EAF with recycled materials as high as that of BOF.	Ok	JAE YOON LEE	Korea Institute for Industrial Economics and Trade(KIET)	Republic of Korea
38551	36	24	36	25	Realzing this potential also requires available scrap, which is an issue in some countries (e.g. China).	OK	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
38553	36	25	36	26	This statement (85% of steel is recycled already) needs a reference. World Steel Association's Steel Statistical Yearbook 2018 report shows 1206 Mt of crude steel produced by oxygen-blown converters (what is referred to as BF-BOF in your report), 472 Mt produced by electric furnaces, and 6 Mt produced by open hearth furnaces in 2016. This means that ~28% of world steel is produced in EAFs.	OK	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
13289	36	39	36	39	the statement about why carbon is needed is not correct. Without the additiona of carbon DRI is not steel but iron. Carbon is needed for all the propoerties that defines the material as steel!	OK	Asa Ekdahl	world steel association	Belgium
36997	36	7	37	30	There is a new process which has been developed in the last years based on sorption enhanced water gas shift for the decarbonisation of BF-BOF which is competitive with existing technology for the decarbonisation of steel. The technology has been scaled up to TRL6 (https://www.stepwise.eu/)	OK, interesting.	Vincenzo Spallina	University of Manchester	United Kingdom (of Great Britain and Northern Ireland)
38555	36	19	37	13	Figure 11.9 shows that average steel intensity and BF-BOF steel intensity are almost 2X greater in terms of energy use (GJ/t) than BAT. Do any of the four options that you discuss here explain how this savings could be realized? The first two are not relevant because we're just discussion BF-BOF steel intensity. It seems that the second two are in the pilot/demonstration stage, so they are probably not what makes up the difference between the current ~20 GJ/t energy intensity of BF-BOF steelmaking and the BAT intensity of 10 GJ/t. I recommend that you provide information to the reader on what can be done *now* to close this existing gap for the very energy-intensive BF-BOF steelmaking that dominates world steel production currently and will continue to into the future. Note that over 90% of steel production in China (the world's largest producer of steel) is via the BF-BOF route.	Partly accepted. Chapter 11 has a focus on new developments since AR5 and options for achieving zero emissions. This is a complicated discussion. Reinvesting for EE in existing BFs may delay and create new lock-in	Lynn Price	Lawrence Berkeley National Laboratory	United States of America

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
8689	36	32	37	13	- The chapter on steel in relation to “sector mitigation pathways and cross sector implications” presents hydrogen reduction ironmaking technologies such as ULCOS and HIsarna, which are being developed in Europe, and states that it is possible by 2050 to produce steel with zero carbon dioxide (CO2) emissions. On the basis of global steel demand forecasts (see the Japan Iron and Steel Federation’s long-term vision), steel production from the natural resource route is considered necessary also in the present century. Under these circumstances, there are only two technological options to reduce CO2 emissions in ironmaking processes to zero: moving from carbon to hydrogen as the principal iron ore reducing agent or processing CO2 emitted in carbothermal reduction processes through carbon capture and storage (CCS) or carbon capture and utilization (CCU). - The amount of hydrogen necessary for hydrogen reduction of iron ore is estimated to be 1,000 Nm3 per ton of crude steel, including heat compensation for the endothermic reaction of hydrogen reduction (see the Japan Iron and Steel Federation’s long-term vision). Therefore, it is essential to consider also whether or not it is possible to supply huge amounts of zero-carbon hydrogen, but there is no argument about this point. In addition, there is also no argument about the feasibility of CCS or CCU in cases where carbothermal reduction continues to be used fully or partially. If it is believed possible to produce steel with zero CO2 emissions by 2050, it is, at the very least, necessary to present quantitative analyses of the above-mentioned critical points, including the supply amount of hydrogen necessary to achieve zero-carbon steel production in the entire world and the amount of CO2 to be processed through CCS or CCU. - If the reducing agent is switched entirely to hydrogen by 2050, it will be necessary to consider how to treat existing facilities. For example, in China and India, where steel production has increased rapidly in the present century, investments have been made for blast furnaces with production capacities of about 200 million tons of crude steel (about 160 million tons in China and about 40 million tons in India) since 2010. In addition, as for investments made by the Chinese steel industry for overseas business operations, facilities with capacities of about 8 million tons of crude steel (about 7.9 million tons in ASEAN member countries) were in operation as of January 2019, and there are plans for facilities with capacities of about 75 million tons (about 50 million tons in ASEAN member countries and 23 million tons in South America). The standard investment recovery period for blast furnaces is more than 50 years, including brick relining every 15 to 20 years. Therefore, it is estimated that there will be production facilities with capacities of about 350 million tons that are still sufficiently operational and whose investment is not recovered as of 2050 (even if this estimate is only for facilities in China and India that are currently recognized, they account for about 30% of blast furnace crude steel production in the world). If the operation of these facilities is stopped for shifting to hydrogen reduction, it will be necessary to provide huge incentives. It will be necessary to keep in mind that extremely large problems may arise from the viewpoint of feasibility.	Good comments, thank you for these suggestions, we will consider how they can be incorporated	HIROYUKI TEZUKA	JFE Steel Corporation	Japan
13291	37	9	37	9	if combined with CCS	OK	Asa Ekdahl	world steel association	Belgium
13293	37	14	37	15	It is not necessarily a choice between these options. There is also CCU, biomass, circular carbon, BF + CCS or a combination of all or some of them!	OK	Asa Ekdahl	world steel association	Belgium
39021	37	16	37	16	Please replace CCUS by "CCU and CSS"	OK	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
8691	37	18	37	26	- It is claimed, “Material efficiency can potentially reduce steel demand by up to 40% based on design for less steel use, long life, reuse, constructability and low contamination recycling.” However, it is essential to verity this claim from the following viewpoints. Meanwhile, at the very least, “long life,” “reuse,” and “recycling” seem to be phenomena that function only after a sufficient amount of steel is accumulated world-wide. - The world-wide amount of accumulation of steel was 4 tons per person as of 2015, and the amount for OECD member countries was about 8 to 12 tons per person (see the Japan Iron and Steel Federation’s long-term vision). In developing countries, the amount of accumulation of steel in the form of civil infrastructure, including arterial roads, bridges, railroads, harbors, and airports, residential houses, office buildings, commercial buildings, distribution warehouses, plants, and non-residential public facilities, including schools, is low. First, following future development of developing countries, the amount of accumulation of steel in the form of these civil infrastructure and buildings is expected to increase. It should be noted that in the stage of development of so-called social infrastructure, there is not much room for promoting “less steel use” from the viewpoint of safety or resilience. In addition, the amount of steel consumption is likely to increase in order to strengthen social infrastructure in case of strengthening of adaptation measures to cope with serious disasters, which are expected to occur frequently with the progress of global warming (for argument, see an IPCC special report on the impacts of global warming of 1.5 °C above pre-industrial levels). Furthermore, “long life,” “reuse,” “recycling,” and other effects that appear only after the completion of building structures do not function in the period of expansion of initial infrastructure investment in developing countries. - Furthermore, also as for automobiles, home electric appliances, and other durable consumer goods, developing countries are assumed to first go through the stage of increase of the stockpile of steel. During this stage, “long life,” “reuse,” and “recycling” do not function to curb demand. - This increase in the amount of accumulation of steel in developing countries (i.e., an expansion of world-wide steel demand) means, in general, an increase in the world-wide amount of accumulation of steel. In order to curb steel demand (i.e., prevent an increase in the world-wide amount of accumulation of steel), it seems necessary to either use steel accumulated in societies of developed countries and provide generated scrap iron sources for the expansion of infrastructure in developing countries (in this case, the amount of scrap that can be used in developed countries will decline) or slow down the pace of accumulation of steel products by curbing the economic development of developing countries. However, it is necessary to sufficiently verify whether or not these phenomena can occur in line with the achievement of the SDGs (sustainable development goals). (Reference) - For example, as for consumption of common steel in Japan by sector, the percentage of consumption by the civil engineering and construction industry was 45.3% in 2003, a decline from 51.1% in 1973, while the percentage of consumption by the manufacturing industry rose from 48.9% to 54.7%. (As for steel demand in Japan, the amount of accumulation of steel was 4 tons per person in 1973 and over 10 tons in 2003.) - In addition, as for production by type of steel in 1973 and 2003, the percentage of special steel products (which are used mainly in the manufacturing industry) increased 10 points, while the percentage of common steel products decreased 10 points.	OK	HIROYUKI TEZUKA	JFE Steel Corporation	Japan
9761	37	18	37	26	Skeptical about whether improving material efficiency will allow a 40 percent decrease in steel demand, as mentioned in the report, due to the characteristics of Korea, where per capita steel demand is far higher than that of other countries.	OK	JAE YOON LEE	Korea Institute for Industrial Economics and Trade(KIET)	Republic of Korea

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
8939	37	22	37	26	It is a stretch to call use of combustible waste gases from iron and steel production carbon capture and use, if that is how the text is intended to be read. The gas is collected due to it's combustible content, which is not CO2. Currently the CO2 is neither captured, used or stored. The use of these waste gases cannot be counted as an emission reduction potential of the steel production process. The measure increases resource efficiency and reduces emissions in another sector (if the replaced current energy use in that sector is fossil in origin). Emissions accounting rules can of course be designed so that this emissions reduction is allocated to the steel industry, but that would imply an equivalent increase in emissions in order to avoid double counting of the emissions reduction. Those emissions may incur costs if taxed or part of an emissions trading system in the sector where the gases are used , which may reduce the cost benefit of buying these gases over other energy carriers. There is also a risk that such a bonus creates false incentives for the steel industry to maximize production of these gases rather than maximizing the efficiency of their own process (Morfeldt and Silveira, 2014; Morfeldt, 2017). Morfeldt, J., & Silveira, S. (2014). Methodological differences behind energy statistics for steel production – Implications when monitoring energy efficiency. Energy, 77, 391–396. https://doi.org/10.1016/j.energy.2014.09.020 Morfeldt, J. (2017). Tracking Emissions Reductions and Energy Efficiency in the Steel Industry [KTH Royal Institute of Technology]. http://urn.kb.se/resolve?urn=urn:nbn:se:kth:diva-205882	Again, CCUS/CCS	Johannes Morfeldt	Chalmers University of Technology	Sweden
13295	37	23	37	23	these gases have a use and an economic value. They should not be refered to as waste bu process gases	OK	Asa Ekdahl	world steel association	Belgium
39023	37	23	37	26	Here a thorough discussion on CCU could be added (but structurally it would be more logical to add it earlier in the chapter, so the first time that the CCU concept is discussed). Here some statements which could be added to this discussion: Carbon mineralization is an emerging approach to remove carbon dioxide (CO2) from the air and/or store it under the form of carbonate minerals such as calcite or magnesite. Mineralization occurs naturally during weathering of silicate materials (e.g., olivine, serpentine, and wollastonite) and rocks rich in Ca and Mg, particularly peridotite, which composes Earth's upper mantle and basaltic lava formed by partial melting of the upper mantle. Because they utilize this naturally available chemical energy, these methods may offer a low cost means to mitigate greenhouse gas emissions. And because the CO2 is locked into solid carbonate minerals, storage has a strong potential to be permanent and nontoxic (NAS, 2019). Pan et al., 2017 estimate that the amount of worldwide reduction by CO2 mineralization using iron and steel slags was approximately 137.5 Mt per year, contributing to a reduction of the global anthropogenic CO2 emissions by 0.38%. Kaliyavaradhan et al., 2017 has estimated that 270 kg of CO2 can be sequestered if 1 t of waste cement is completely carbonated. Di Maria et al., 2020 conducted an LCA of carbonated steel slag including CO2 capture and confirm that mineral carbonation is a negative-carbon-footprint technology, since the amount of CO2 taken up and stored during the process is higher than the amount of CO2 emitted, considering the whole life cycle. While comparing the findings to Portland cement concrete blocks, they report GHG emission reductions of up to 77%. At endpoint, they report that concerning the damages to human health and ecosystems, the carbonated blocks have a lower impact compared to the traditional PC-based concrete, and an overall positive environmental impact. (REFERENCES: Kaliyavaradhan et al., 2017, J. CO2. Utili., 20, 234-242./Pan et al., 2020: CO2 Mineralization and Utilization using Steel Slag for Establishing a Waste-to-Resource Supply Chain, Nature Scientific Reports 7, 17227./ Di Maria et al, 2020: Environmental assessment of CO2 mineralisation for sustainable construction materials, International Journal of Greenhouse Gas Control, 93./NAS, 2019, Negative Emissions Technologies and Reliable Sequestration, The National Academies Press.)	Again, CCUS/CCS	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
14299	37	26	37	26	Addition: "Furthermore, CCU technologies like CO2 mineralisation of steel slags for the production of building materials can further reduce GHG emissions (Chen at al., 2016, http://dx.doi.org/10.1016/j.jclepro.2016.02.072; di Maria et al., 2020; https://doi.org/10.1016/j.ijggc.2019.102882; Ghasemi et al., 2017, https://doi.org/10.1016/j.egypro.2017.03.1675; Kirchofer et al., 2013, https://doi.org/10.1016/j.egypro.2013.06.510; Lee et al., 2020, https://doi.org/10.1016/j.jcou.2019.12.005, Pan et al., 2017, https://doi.org/10.1038/s41598-017-17648-9; Mattila et al., 2017, http://dx.doi.org/10.1016/j.jclepro.2014.05.064)"	Again, CCUS/CCS	Anastasios Perimenis	CO2 Value Europe (Association) - CCU Offiver	Belgium
300	37	31	37	31	It is suggested that you change the title of this section to refer only to cement. There are other types of concrete created without the use of cement, such as hot mix asphaltic concrete (HMAC). Another alternative would be to add the modifier "cementitious," such as "Cement and cementitious concretes and composites."	OK	Rebecca Harjo	NOAA/National Weather Service	United States of America
38557	37	31	37	46	Technically, the energy is used to produce clinker. This should be at least introduced in this paragraph. Otherwise, excellent section on the cement sector.	OK	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
40235	37	32	37	32	I suggest to change glue by binder	OK	Ana Ines Fernandez	University of Barcelona	Spain
44843	37	37	37	37	Replace ‰ with % (see page 41 line 34)	OK	Véronique Waroux	Planète-A	Belgium
2225	37	38	37	38	Reference: M. A. Sanjuán; E. Menéndez; C. Argiz; A. Moragues. Coal bottom ash research program focused to evaluate a potential Portland cement constituent. II International Conference on Concrete Sustainability, ICCS16. Madrid, 13-15 June, 2016. CIMNE Ed. 532-543. ISBN: 978-84-945077-7-9.	OK	Miguel Angel Sanjuán	Technical University of Madrid	Spain
2227	37	38	37	38	It should be % instead of %o.	OK	Miguel Angel Sanjuán	Technical University of Madrid	Spain
12545	37	38	37	38	Please addd: "7,4% (Sanjuán et al 2020)" according to reference: 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	OK, total cement/concrete emisisons	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
20745	37	38	37	38	Please add: "7.4% (Sanjuán et al. 2020)." Reference: 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	OK	Miguel Angel Sanjuán	Technical University of Madrid	Spain
44845	37	39	37	39	Delete "e.g."	Ok	Véronique Waroux	Planète-A	Belgium
11381	37	39	37	42	Sentence, " Typically, about 40%...... from the calcium carbonate decomposition (IEA 2018A)", appears to be confusing. One emission-type should be termed as fuel related emission and the other type should be termed as process emission arising out of decomposition of CaCO3 or other carbonate materials.	OK	PINAKI SARKAR	CSIR-CENTRAL INSTITUTE OF MINING AND FUEL RESEARCH	India
10733	37	42	37	44	I strongly support this draft, so please add additional references as follow; "Some of CO2 is reabsorbed into concerete producets and can be seen as avoided the decades long life of the products; estimates of this flux vary between 15 and 27% of the direct emissions (Schneider 2019; R. Andersson 2019*1; S. Hakan 2018*2). *1; https://www.sciencedirect.com/science/article/pii/S0008884619301929 *2; https://cembureau.eu/media/1753/ivl-report-co2-uptake-in-cement-containing-products-isbn-number-b2309.pdf	OK	NAOKI AOKI	Japan Cement Association	Japan
44847	37	43	37	43	Replace ‰ with %.	OK	Véronique Waroux	Planète-A	Belgium
2231	37	44	37	44	Please, add after Schneider 2019: "Sanjuán et al 2020". Please, add updated reference: 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	OK	Miguel Angel Sanjuán	Technical University of Madrid	Spain
12871	37	44	37	44	key recent references supporting the values of 15 and 27% are missing and should be added "Some of CO2 is reabsorbed into concerete producets and can be seen as avoided the decades long life of the products; estimates of this flux vary between 15 and 27% of the direct emissions (Schneider 2019; R. Andersson 2019*1; S. Hakan 2018*2). *1; https://www.sciencedirect.com/science/article/pii/S0008884619301929 CO2 uptake in cement-containing products - Background and calculation models for IPCC implementation IVL B2309 *2; https://www.ivl.se/toppmeny/publikationer/publikation.html?id=5656	OK, additional references requested from multiple sources	Claude Lorea	Global Cement and Concrete Association	Belgium
12873	37	44	37	44	there are other developments worth being added here Some companies (e.g. Carboncure) are utilizing this CO2 absorbing characteristic of cement to mix waste CO2 into concrete as a hardening agent, both to dispose of the CO2 and improve the final concrete. Another important development in that context is the FastCarb project which aims at accelerating carbonation of recycled concrete. Finally, one should also mention Solidia which is utilising CO2 for concrete production Reference https://www.solidiatech.com/ https://fastcarb.fr/en/program/experimental-approach-in-the-laboratory/	Ok, will review	Claude Lorea	Global Cement and Concrete Association	Belgium
14301	37	46	37	46	Addition: "Various studies have indeed reported GHG reduction potential through carbonation of waste concrete or CO2 mixing (Zhang et al., 2020, https://doi.org/10.1016/j.rser.2019.109495; Lim et al., 2019, https://doi.org/10.1088/1748-9326/ab466e; Kaliyavaradhan et al., 2017, http://dx.doi.org/10.1016/j.jcou.2017.05.014; Andrade et al., 2018, https://doi.org/10.1016/j.conbuildmat.2017.11.089)	OK	Anastasios Perimenis	CO2 Value Europe (Association) - CCU Offiver	Belgium
20487	37	31	39	10	fuel related GHG emissions can be reduced to zero, while limestone related emissions are more complicated, however this represents CCU potential to be coupled with Power-to-X options, as discussed by Farfan et al. (https://www.sciencedirect.com/science/article/pii/S0959652619302185)	Interesting, thank you	Christian Breyer	LUT University	Finland
36791	37	31	39	10	A new process is currently under development (TRL6 or above) based on Caclium ooping and developed in the framework of H2020 (http://www.cleanker.eu/the-project/project-contents). And forecasting a costo of CO2 capture <25 eur/t. Advise to add in the list of possible option.	OK	Vincenzo Spallina	University of Manchester	United Kingdom (of Great Britain and Northern Ireland)
302	38	1	38	2	It is suggested that you remove the work concrete in the first portion of this sentence. The sentence is about emissions from cement production, not concrete production. Also the goal is to make stronger concrete mixes through better mixing of aggregates, not a stronger cement.	OK	Rebecca Harjo	NOAA/National Weather Service	United States of America
304	38	7	38	7	It is suggested to change "Because so much of the emissions from concrete.." to something like "Because so much of the emissions from packaged concrete mixes."	Noted thank you, we will check	Rebecca Harjo	NOAA/National Weather Service	United States of America
44945	38	7	38	7	"produce"clinker instead of "make" clinker	OK	Andreas Schroeder	International Energy Agency IEA	France
11385	38	7	38	14	Comment: Substantial proportion fly ash or BF slag is known to be in use in cement composition after blending those with clinker. The higher the amount of FA or BF slag the lower will be the GHG intensity.	OK	PINAKI SARKAR	CSIR-CENTRAL INSTITUTE OF MINING AND FUEL RESEARCH	India
306	38	10	38	10	The admixtures are added to replace only a portion of the cement, not the entirety of the cement within the mix. Please revise accordilngly.	OK	Rebecca Harjo	NOAA/National Weather Service	United States of America
44849	38	10	38	10	These substitute materials are not widely available on the market.	Yes, because in general they still need to be approved.	Véronique Waroux	Planète-A	Belgium
2233	38	11	38	11	Please, after "...materials." add: "Sanjuán et al (2016) have evaluated the CO2 emission reduction potential in the cement sector considering the applicability and technological maturity. They concluded that clinker substitution has both characteristics: a high applicability and a high technological maturity. Therefore, it is feasible from a technological and economic perspective. The clinker substitution rate constantly increased during the last decade and alos there exits still a significant potential for improvement." Reference: M. A. Sanjuán; E. Menéndez; C. Argiz; A. Moragues. Coal bottom ash research program focused to evaluate a potential Portland cement constituent. II International Conference on Concrete Sustainability, ICCS16. Madrid, 13-15 June, 2016. CIMNE Ed. 532-543. ISBN: 978-84-945077-7-9. https://www.rilem.net/global/gene/link.php?doc_link=/media/event/2015112606_ICCS16Madridflyer032015b.pdf	To be considered	Miguel Angel Sanjuán	Technical University of Madrid	Spain
44851	38	12	38	12	Replace "heated" with "calcined."	OK	Véronique Waroux	Planète-A	Belgium

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
308	38	15	38	19	This paragraph is discussing concrete, not cement. It is recommended that the word "cement" with "concrete" throughout this paragraph.	OK	Rebecca Harjo	NOAA/National Weather Service	United States of America
28017	38	24	38	25	IPCC states, "For this reason, CCS technology, which could capture just the process emissions…"CCS for cement manufacturing is an opportunity cost. It reduces only CO2. The same money used for the CCS equipment and energy should be used instead to replace coal, gas, or oil fossil plants with wind, water, or solar power and reduce more CO2 while also reducing 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. Thus, there is no situation where using CCS/U for industry is better than spending the same equipment and energy money simply on replacing fossil fuels. Please clarify this.	Same comments on CCS/CCUS as before, to be treated once	Mark Jacobson	Stanford University	United States of America
14303	38	25	38	25	Correction: Please replace "CCS" with "carbon capture" becasue this is only about capture and not storage	OK	Anastasios Perimenis	CO2 Value Europe (Association) - CCU Offiver	Belgium
44853	38	25	38	36	The problem with the LEILAC project is that we don't know what to do with the cleaned CO2. Its implementation on an industrial scale (stage 2) does not seem to be confirmed yet.	CCS	Véronique Waroux	Planète-A	Belgium
14305	38	28	38	28	Correction: Please replace "CCS" with "carbon capture" becasue this is only about capture and not storage	OK	Anastasios Perimenis	CO2 Value Europe (Association) - CCU Offiver	Belgium
12875	38	33	38	33	A recent report was published by the CSLF and should be referred to as it provides a good overview of CSLF technologies https://www.cslforum.org/cslf/sites/default/files/documents/Task-Force-on-CCUS-for-Energy-Intensive-Industries-Final-Report.pdf	OK	Claude Lorea	Global Cement and Concrete Association	Belgium
10735	38	34	38	35	The draft text should be ammended as following red text; The energy-related emissions of cement production can also be reduced by using alternative fuels and biogenic energy sources, hydrogen or electricity for generating the high-temperature heat at the calciner. For instance, the cement industry utilizes industrial wastes including waste plastics for clinker production by saving 15 up to 20% of thermal energy consumption (Y. Izumi, 2014*) *: Key Engineering Materials Vol.617 (2014) pp 50-58 Online available since 2014/Jun/24 at www.scientific.net © (2014) Transe Tech Publications, Switzerland doi:10.4028/www.scientific.net/KEM617.50	OK	NAOKI AOKI	Japan Cement Association	Japan
28019	38	34	38	35	IPCC states, "The energy-related emissions of cement production can also be reduced by using biogenic energy sources, hydrogen or electricity…" While using hydrogen or direct electricity can reduce emissions in industry, there is no evidence that using biogenic energy reduces emissions (which include air pollutant and carbon emissions as well as upstream emissions from producing the fuel). Biomass is burned, so that will create air pollution, which leads to substantial air pollution and climate impacts Jacobson, M.Z., Effects of biomass burning on climate, accounting for heat and moisture fluxes, black and brown carbon, and cloud absorption effects, J. Geophys. Res., 119, 8980-9002, doi:10.1002/2014JD021861, 2014; Jacobson, M.Z., Short-term effects of controlling fossil-fuel soot, biofuel soot and gases, and methane on climate, Arctic ice, and air pollution health, J. Geophys. Res., 115, D14209, doi:10.1029/2009JD013795, 2010.	OK, need to be elaborated upon	Mark Jacobson	Stanford University	United States of America
2229	38	41	38	41	It should be "kiln" instead of "furnace".	OK	Miguel Angel Sanjuán	Technical University of Madrid	Spain
44855	39	3	39	3	These clinkers are available in derisory quantities.	To be expanded upon	Véronique Waroux	Planète-A	Belgium
44857	39	4	39	4	These solutions, which appear to be ideal (negative emissions), should be demonstrated applicable by references.	OK	Véronique Waroux	Planète-A	Belgium
14307	39	5	39	5	Addition: Mineral carbonation is an emerging approach to remove carbon dioxide (CO2) from the air and/or store it under the form of carbonate minerals such as calcite or magnesite. Mineralization occurs naturally during weathering of silicate materials (e.g., olivine, serpentine, and wollastonite) and rocks rich in Ca and Mg, but it can be purposefully accelerated to mitigate GHG emissions and generate construction materials. And because the CO2 is locked into solid carbonate minerals, storage has a strong potential to be permanent and nontoxic (NAS, 2019, https://doi.org/10.17226/25259)	Interesting, but it's about negative emission, not making cement.	Anastasios Perimenis	CO2 Value Europe (Association) - CCU Offiver	Belgium
14309	39	5	39	5	Addition suite: Several natural minerals can be carbonated ((Bodénan et al., 2014, http://dx.doi.org/10.1016/j.mineng.2014.01.011; Giannoulakis et al., 2014, http://dx.doi.org/10.1016/j.ijggc.2013.12.002; Huang et al., 2019, https://doi.org/10.1016/j.jclepro.2019.118359; Nduagu et al., 2013, http://dx.doi.org/10.1016/j.apenergy.2013.01.049) but also several industrial waste fractions (Bobicki et al., 2012, https://doi.org/10.1016/j.pecs.2011.11.002, Kirchofer et al., 2013, https://doi.org/10.1016/j.egypro.2013.06.510; Pasquier et al., 2016, http://dx.doi.org/10.1016/j.ijggc.2016.04.030; Lim et al., 2019, https://doi.org/10.1088/1748-9326/ab466e; di Maria et al., 2020, https://doi.org/10.1016/j.ijggc.2019.102882)	Will consider	Anastasios Perimenis	CO2 Value Europe (Association) - CCU Offiver	Belgium
11383	39	15	39	16	Note: As India is yet to communicate its official emission numbers beyond 2014, the numbers presented as global GHG emission estimates from various assessments may be recorded here as provisional number. This should be mentioned in the foot note against such statement mentioned in the text.	OK	PINAKI SARKAR	CSIR-CENTRAL INSTITUTE OF MINING AND FUEL RESEARCH	India
29131	39	18	39	18	Please see if this footnote is needed	OK	Minal Pathak	Ahmedabad University	India
14311	39	29	39	29	Correction; Please replace "CCS" with "CCU" because the CO2 is further used and not stored.	CCS/CCUS again; to be dealt with in common	Anastasios Perimenis	CO2 Value Europe (Association) - CCU Offiver	Belgium
14313	39	30	39	30	Addition: Indeed, the potential of CO2 as chemical feedstock for GHG reduction in the chemical industry is underlined by many recent studies (Hepburn et al., 2019, https://doi.org/10.1038/s41586-019-1681-6; Kätelhön et al., 2018, https://doi.org/10.1073/pnas.1821029116; Thonemann and Pizzol, 2019, (https://doi.org/10.1016/j.apenergy.2020.114599)	Ok, can try to add these as references.	Anastasios Perimenis	CO2 Value Europe (Association) - CCU Offiver	Belgium
34465	39	31	39	37	A good way to reduce ammonia consumption is to control fertilizers spreading and to replace partially nitric fertilizers by natural nitrogen which avoids N2O emissions	To be addressed, send comment to the demand chapter	Emmanuel RAUZIER	NGO Association negaWatt	France
20489	39	12	41	30	chemical industry and CCU should be better linked as pointed out in Käteljön et al. (https://www.pnas.org/content/116/23/11187)	OK, see two above	Christian Breyer	LUT University	Finland

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
36381	39	12	41	30	See the comment No.3	OK	Shigetaka Seki	Consumer Product Safery Association	Japan
36793	39	31	41	31	a lot of emphasis is given to methane pyrolisis which is not justified given the current state-of-the-art development. This comment is also inherent to the discussion on Hydrogen production. Currently costs and studies which are consistent and validated according to the results provided by techno-economic and feasibility assessment. Also the unknown existing carbon capture rate, low understanding on the material development and process economics, together with the very low TRL level makes this emphasis not justified	No, there isn't a lot of emphasis on pyrolysis. The TRL level is stated as low.	Vincenzo Spallina	University of Manchester	United Kingdom (of Great Britain and Northern Ireland)
36795	39	31	41	31	Given the existing costs of oxygen prodcution and CO2 separation which are determining the high cost of CO2 capture for chemicals and hydrogen production, I suggest to consider also the possibility to use solid looping technology. At the moment, an European project (FP7 - ASCENT) has been completed presenting the possibility of using sorption enhanced reforming for the production of pure hydrogen and ammonia (doi:10.1016/j.ijggc.2019.03.026,handle:10261/183897). A new EU project on coal-to- liquid fuels based on chemcial looping combustion is currently running to demonstrate the technology up to TRL7 (https://clara-h2020.eu/). finally a TRL7 demonstration prototype has been constricuted on direct syngas gasification from the Ohio state university in collaboartion with Babcock & Wilcox Power Generation Group (B&W) and the DOE	Will try to include	Vincenzo Spallina	University of Manchester	United Kingdom (of Great Britain and Northern Ireland)
12981	40	7	40	7	Feedstock - fossile ressources - should be translated to English	OK	Robin White	Environment & Climate Change Canada, Government of Canada	Canada
12983	40	10	40	10	Figure 11.10 would benefit from more explanation	Noted thank you	Robin White	Environment & Climate Change Canada, Government of Canada	Canada
40237	41	1	41	30	Figure 11.11 should be mentioned in the text	Noted thank you	Ana Ines Fernandez	University of Barcelona	Spain
39025	41	5	41	8	Please rephrase: The methanol can be produced using as substrate green hydrogen (produced by water electrolysis using RE) and 1) CO2 captured from ambient air or at point sources), 2) CO2 from biomass, and 3) fossil CO2 from industrial processes (this should be only for a transition period).	OK	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
16335	41	37	41	43	In the text describing light manufacturing and industry, consider adding a brief description of what light manufacturing and industry entails, e.g. what goods are manufactured in this process, as an aid to the reader, for clarity.	OK	Daniel Helman	College of Micronesia-FSM	Micronesia, Federated States of
9629	41	20			This comment could equally apply to many sections in this chapter. It is important to mention the enormous sunk cost that exists in current industry installations and the typical operational lifetimes associated with major facilitiies. Giving a specific example would be helpful - for instance estimating the number of cost and operational lifetime of world-scale ethylene crackers. These are similar in scale to large power plants (>$1B capital expense to build) so the same issues that exist with "replacing" the legacy electricity fleet also plague every industyr sector.	OK	David Sholl	Georgia Institute of Technology	United States of America
16333	41	32			In Subsection 11.4.1.4 Other industry sectors, consider including the emissions of GHG from manufacture of silicon chips for the Information and Communications Technology (ICT) sector. Since computer chips are such an integral part of the global economic system, explicitly including a short treatment of the emissions associated with their manufacture will be important to the reader even if it comprises a very small portion of the total industrial sector's emissions.	NO, too detailed	Daniel Helman	College of Micronesia-FSM	Micronesia, Federated States of
25227	42	6	42	6	Delete "with the OECD forecasting"	OK	Eleni Kaditi	Organization of the Petroleum Exporting Countries (OPEC)	Austria
44947	42	19	42	20	"1.5 tonnes of direct CO2 are currently emitted for each tonne aluminium as the graphite electrodes are depleted and combine with oxygen" - Questions arise. Are these classified as process emissions (yes, as mentioned later on this page at line 29)? Do they occur at the end of each production cycle of an electrode? How often are electrodes changed?	OK	Andreas Schroeder	International Energy Agency IEA	France
44949	42	24	42	24	"increasing […] from the 20–25% global average is a key emissions strategy." Increasing to which target value?	Unclear comment, unfortunately misplaced page wise	Andreas Schroeder	International Energy Agency IEA	France
8941	42	26	42	31	Inert anodes are an interesting emissions abatement option. However, it should be clarified that the main contribution of using them is to eliminate the process emissions, but this comes at the cost of increased electricity demand per kg of Al produced. See Solheim, 2018 and Saevarsdottir et al., 2020. Saevarsdottir, G., Kvande, H., & Welch, B. J. (2020). Aluminum Production in the Times of Climate Change: The Global Challenge to Reduce the Carbon Footprint and Prevent Carbon Leakage. JOM, 72(1), 296–308. https://doi.org/10.1007/s11837-019-03918-6 Solheim, A. (2018). Inert Anodes – the Blind Alley to Environmental Friendliness? Light Metals 2018, 1253-1260 (Proceedings, 147th TMS Annual Meeting, Phoenix, Arizona, 11-15 March, 2018).	Thank you. Lenght does not allow all detail	Johannes Morfeldt	Chalmers University of Technology	Sweden
44951	42	29	42	30	What is an electrode of proprietary nature? Is it an electrode technology which is privately owned and not publicly available?	OK, needs to be developed	Andreas Schroeder	International Energy Agency IEA	France
2625	42	31	42	31	Add to the end of this paragraph that non-carbon electrode technology is also applicable to rare earth manufacture, e.g. Nd.	OK	Michael Czerniak	Atlas Copco - Edwards	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
8943	42	32	43	5	Copper may be worth discussing in more detail since demand for copper is likely to increase with deployment of renewable energy technologies that often require large amounts of copper, as well as electrification in general and of transportation specifically. See for example Moreno-Leiva et al., 2020. There are also studies pointing to increased energy use per produced kg of copper in the future due to decreasing ore grades. Ore grades are likely to decrease further if demand is supplied by increased production of virgin copper resulting in increased extraction. See for example Moreno-Leiva et al., 2020 and Elshkaki et al., 2016. Moreno-Leiva, S., Haas, J., Junne, T., Valencia, F., Godin, H., Kracht, W., Nowak, W., & Eltrop, L. (2020). Renewable energy in copper production: A review on systems design and methodological approaches. Journal of Cleaner Production, 246. https://doi.org/10.1016/j.jclepro.2019.118978 Elshkaki, A., Graedel, T. E., Ciacci, L., & Reck, B. (2016). Copper demand, supply, and associated energy use to 2050. Global Environmental Change, 39, 305–315. https://doi.org/10.1016/j.gloenvcha.2016.06.006	OK	Johannes Morfeldt	Chalmers University of Technology	Sweden
35013	42		56		How could energy system transition help in attaining industrial system transition?	accepted: the role of energy system transition (e.g. reenewable energy based electricity) will be explained particularly in section 11.4.2	Pramod K Singh	Institute of Rural Management Anand	India
40239	43	3	43	5	Some hydro and electrometallurgical processes are no longuer used because of their pollution potential with the available technology	OK	Ana Ines Fernandez	University of Barcelona	Spain
8849	43	13	43	13	This paper: doi: 10.1111/jiec.12997 quantifies a mitigation cost of USD 67 per tonne CO2 for the H2 DRI EAF route	OK	Saygın Değer	SHURA Energy Transition Center	Turkey
44953	43	14	43	14	Who is PPI?	Pulp and paper industry	Andreas Schroeder	International Energy Agency IEA	France
6069	43	17	43	17	Please delete the comma after "industry".	OK	Andreas Oberheitmann	FOM University of Applied Sciences	Germany
14315	43	29	43	31	Addittion: It is however an area with high potential for GHG reduction and introduction of new business models in the chemical sector. As IEA 2019 higlight in their newest report, CO2 will be an important raw material for products requiring carbon. In the transition to a net-zero CO2 emission economy, the CO2 would increasingly have to be sourced from biomass or the air. (IEA, 2019, https://www.iea.org/reports/putting-co2-to-use)	OK, could require some work to introduce	Anastasios Perimenis	CO2 Value Europe (Association) - CCU Offiver	Belgium
40241	43	39	43	39	technological instead technolgoical	OK	Ana Ines Fernandez	University of Barcelona	Spain
44859	43	39	43	39	Correct the word "technological"	OK	Véronique Waroux	Planète-A	Belgium
38559	43	33	46	1	This is a very ambitious section and table to compile! If it can be done carefully and using comparable values, it will be quite interesting. I caution, though, that these reports have different base years, different BAU assumptions, etc.	OK	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
8945	44	13	44	13	"Current intensity – EAF (depends on electricity intensity)" It should be noted that EAF either needs scrap or sponge iron as feedstock. the GHG reductions stated here are in relation to scrap-based EAF. In other cases, EAF should be seen as integrated with for example NG-DRI, which means that the emissions reduction potential is significantly lower. Also the Scrap-based EAF route is limited by availability of scrap and level of recycling.	OK	Johannes Morfeldt	Chalmers University of Technology	Sweden
8973	44	13	44	13	"Methane or methanol from H2 & COx (CCUS for excess). Maximum -50% reduction if C source is FF" See comment on page 37, lines 22-26 above.	Unclear comment	Johannes Morfeldt	Chalmers University of Technology	Sweden
38561	44	13	44	13	For each sector, you need to add a row (and data) for energy efficiency.	Interesting, this is for new processes, but we can try	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
39027	44	13	44	13	In table 11.4, CCUS should be splitted in CCU and CCS for the reasons stated above. The two terms do not have the same implications and this brings misunderstanding in the current version of the table.	CCUS/CCS thing again, to be dealt with in common	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
44861	44	13	44	13	Table 11.4: Explain and scale to TRL	Noted, more explanation is warranted.	Véronique Waroux	Planète-A	Belgium
30909	45		45		For table entry "CCUS of post-combustion CO2 diluted in nitrogen" under "Cross-cutting", see same comment as above.	Unclear comment	Jasmin Kemper	IEA Greenhouse Gas R&D Programme (IEAGHG)	United Kingdom (of Great Britain and Northern Ireland)
34467	46	1	47	21	A good way to reduce plastics emissions is biosourced plastics devlopment especially for packaging	Agree, and biomass as feedstock is refered to in several other places. The Box is about fossil production emissions	Emmanuel RAUZIER	NGO Association negaWatt	France
24651	46	2	47	21	The box on plastic is useful, but there is a disconnect between this and the main text, which emphasizes the possibility of achieving a circular economy in plastic. It should be obvious that, even if technical, economic, and policy barriers are overcome, a circular economy is not possible while rapid production growth is occurring. The box should point out the current low levels of plastic recycling (2-4% according to the Ellen MacArthur Foundation and Jan Dell), the distinction between downcycling and recycling (downcycling does not replace virgin product, so has drastically reduced environmental benefits and does nothing to achieve the circular economy), and the need to arrest growth to achieve circularity. It is also worth mentioning that the current fracking boom is leading to ever-cheaper sources of virgin plastic, inhibiting the growth of the recycling industry.	Point well taken but better note the recycling probelms in 11.4.1.3 Chemicals or in Circular Economy rather than the Box.	Neil Tangri	GAIA	United States of America
27483	46	2	47	21	Add latest data about GHG emissions in plastic lifecycle and incineration of plastic: "By 2050, the greenhouse gas emissions from plastic could reach over 56 gigatons—10-13 percent of the entire remaining carbon budget. In 2019, the production and incineration of plastic will produce more than 850 million metric tons of greenhouse gases—equal to the emissions from 189 five-hundredmegawatt coal power plants.Hamilton, Lisa Anne, et al. "Plastic & Climate: The Hidden Costs of a Plastic Planet." Center for International Environmental Law (CIEL) (2019).	Good point but we do not agree that the Box is the place to refer to remaining carbon budget. We will try to find a way/place to provide this information.	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
36383	46	2	47	21	Degradation and difficulty of sorting in collection are major hurdles for recyling plastics, as well as the resource needed for recyling. The PVC pipes and fitting are an exceptional case in which degradation is not much significant as compared to other plastics, and have strong advantage due to the longevity as compared to single use applications, however, cannot escape from the problem of degradation. https://doi.org/10.1007/s10163-015-0421-8 In most cases, thermal recovery is the most rational and least emitting option. Recycling for the sake of recycling does not make sense for CO2 emissions reduction. https://www.jstage.jst.go.jp/article/jsmcwm/25/0/25_73/_pdf/-char/en	This is a good point but not for the Box. Material degradation will be noted in 11.4.1.3	Shigetaka Seki	Consumer Product Safery Association	Japan
11387	47	10	47	10	'butcan' would be 'but can'	Thank you	PINAKI SARKAR	CSIR-CENTRAL INSTITUTE OF MINING AND FUEL RESEARCH	India
33027	47	12	47	13	I would check this statement - I think the proportion that is burned is lower.	Noted, thank you, we will check	Peter Levi	International Energy Agency	France
11389	47	13	47	13	'with 2015-2050 incremental capital investments' would be 'with incremental capital investments between calendar year 2015 and 2050'	The suggested change does not improve the sentence.	PINAKI SARKAR	CSIR-CENTRAL INSTITUTE OF MINING AND FUEL RESEARCH	India
44863	47	27	47	27	It is important to point out that the image of the "profit industry" must change. We are entering a more "responsible" era.	rejected: responsibility is not ncessarily in conflict with gaining profits, it depends on the regulation and how strict the rules are; btw: the role of changing demand patterns is part of the portfolio discussion in section 11.3 and chapter 5	Véronique Waroux	Planète-A	Belgium
44199	47	42	47	42	Please do consider including analysis from Napp et al. (2019) The role of advanced demand-sector technologies and energy demand reduction in achieving ambitious carbon budgets, Applied Energy, 238, 351-367, https://doi.org/10.1016/j.apenergy.2019.01.033 This paper considered more technologically advanced decarbonisation routes for industry explicitly, in part building on Napp et al. (2014) A review of the technologies, economics and policy instruments for decarbonising energy-intensive manufacturing industries, Renewable and Sustainable Energy Reviews, 30, 616-640, 10.1016/j.rser.2013.10.036	accepted, will be discussed in 11.4.2.2	Ajay Gambhir	Imperial College London	United Kingdom (of Great Britain and Northern Ireland)
29067	48	19	48	19	Scenarios are plausible futures. Please consider alternate title	rejected: pathways is a widely used term in AR6	Priyadarshi Shukla	Ahmedabad University	India
38563	48	24	48	27	Regarding global studies, what about the IEA's WEO 2019 (you cite it as IEA 2019c)? Also, just presenting studies on Europe seems a bit unbalanced since most of global industrial production is in China. I suggest that you at least include studies about China to balance the studies about Europe, but it would be preferable if you could include studies from other economies too. One suggested study for China is Zhou et al., 2019 (https://doi.org/10.1016/j.apenergy.2019.01.154) but there are many by Chinese organizations who have developed "mid-century" strategy scenarios during the past few years.	accepted: text will be revised accordingly	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
38565	48	32	48	34	IEA's WEO 2019 could be included here too.	accepted: text will be revised accordingly	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
38567	48	39	50	8	You cite the IEA's 2017 ETP (IEA 2017a) and plot its findings in Figure 11.13, but your analysis of the B2DS scenario does not report the *actual* findings of the report, which are: "Of the 217 Gt cumulative direct CO2 emissions reductions in the B2DS, energy efficiency and BAT deployment contribute the largest share (42%), followed by innovative processes and CCS (37%). Switching to lower carbon fuels and feedstocks accounts for 13% of the reductions, with the remaining 8% from material efficiency strategies in manufacturing processes." Instead, on page 49, lines 14-17, you state "Figure 11.13 compares these four different mitigation scenarios in respect to how strongly they rely on individual mitigation strategies in the industry sector, namely material demand reductions, the use of CCS and the final energy use of the (potentially) low or zero-carbon energy sources biomass, hydrogen and electricity." Where is energy efficiency and BAT deployment? You can't just cut these out of this assessment!	accepted role of energy efficiency will ge highlighted	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
38569	48	39	50	8	Figure 11.3 leaves out energy efficiency for each study. Please add it in for each of these references. Please also add information on the energy efficiency strategies, etc. within the text that describes this figure.	accepted role of energy efficiency will ge highlighted	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
38571	49	33	49	35	This may be true, but it is also very country/economy/region-specific. Strategies for Europe or for economies with decarbonized electricity systems will be quite different from strategies for other economies. You could at least note this since it is also a broad conclusion that should be able to be drawn from the literature.	accepted: text will be revised accordingly	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
28717	49	33	49	39	Suggest noting that for CCS, while it is technically not impossible to achieve >95% CO2 avoidance rate, for industrial processes the cost optimal capture rates are often much lower. Suggested reference: Kuramochi, T., Ramírez, A., Faaij, A., Turkenburg, W., 2012. Comparative assessment of CO2 capture technologies for carbon-intensive industrial processes. Prog. Energy Combust. Sci. 38, 87–112.	rejected: the technical details (including the CO2-reduction rates) arediscussed earlier in the chapter (i.e. section 11.3), the frame "very strong reduction" used in the text fits with the 955 CO2 avoidance rate	Takeshi Kuramochi	NewClimate Institute	Germany
37567	49	33	50	8	Emission reductions achieved wolud rather be presented for various points of time than only in 2050. For policy purposes, incl. NDCs, and for interlinkages with chapters 3, 4 and 6, it is essential to include reductions achieved in 2030 and 2040.	accepted: revised version will have different figure showing the whole period from 2020 to 2050	Michiel Schaeffer	Climate Analytics	Netherlands
29135	50	2	50	4	Please check consistency with reference to sector specific scenarios, where these are compared in Section 11.3 (reference scenarios, BAU, IEA low carbon scenarios and LED). Specifically tables 11.3 and 11.5 and Figure 11.13	accepted: duplication will be avoided in the revised text	Minal Pathak	Ahmedabad University	India
38573	50	13	50	13	Why was Figure 11.13 from the internal draft (showing the IEA's CTS scenario compared to the RTS for 2017-2060 from the IEA's 2019 WEO) removed from this FOD? This figure clearly illustrates the relative importance of energy efficiency and BAT deployment (38%) vs other options and is an important study that should be better included in this Industry Chapter of AR6.	accepted: role of energy efficiency will be better highlighted in the revised text, will see where it can placed best	Lynn Price	Lawrence Berkeley National Laboratory	United States of America

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
38575	50	14	50	21	Why was most of the text related to the previous Figure 11.13 and Figure 11.14 from the internal draft (page 41, line 19 to page 43, line 22) removed? Why was the previous Figure 11.14 removed? This is important information and should be re-instated in this chapter.	rejected: see above, cut of text was necessary due to limited availability of space, but sse above energy effiiciency will be discussed	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
44865	50	18	50	18	Correct "difference"	accepted	Véronique Waroux	Planète-A	Belgium
24653	50	22	50	24	It is hard to square this statement with the rapid growth in plastics and cement. If stabilizing or reducing production levels is a part of the strategy to achieve near-zero carbon emissions, it should be stated explicitly, as this demand (which most in the business and economics wolds, will view as "stagnation") is likely to be more challenging than any technological hurdle.	rejected: different scenarios show that even with growing material demand a pathway close to zero emissions is possibel, however agreement that potential role of demand reduction is an important strategy (as such it is part of the discussion of options in 11.3m while only a few scenarios include this option in their assessment)	Neil Tangri	GAIA	United States of America
44955	50		50		Figure 11.13: Pleae be aware that IEA harmonises its scenario names. Stated Policy Scenario and Sustainable Development Scenario are the common names used for scenarios at IEA as of WEO2019 cycle.	accepted	Andreas Schroeder	International Energy Agency IEA	France
44867	51	25	50	25	Figure 11.14: Explain Survival probability and line 23	accepted: short text will be added	Véronique Waroux	Planète-A	Belgium
44957	51	19	51	23	This section has quite obvious, general and true statements. But what is the conclusion? Is China particularly difficult regarding the stock? Any key results such as the amount of cumulative emissions locked in? As a general comment: The chapter would benefit from a deeper look into stocks, lcok/ins and cumulative emissions effects.	accepted: will be added	Andreas Schroeder	International Energy Agency IEA	France
36385	51	32	53	19	Please see comments No.1, 3, 4, 9. It is true that the price changes of the materials have modest impacts on the price of the final products. However, as the climate mitigation policy needs very comprehensive measures to be significant, the overall price change of the final products should be much greater than as shown here.	accepted: text will be revised accordingly	Shigetaka Seki	Consumer Product Safery Association	Japan
44869	52	3	52	3	Table 11.5 identical to Table 11.2, why replace it?	accepted: duplication of table will be avoided in revised text	Véronique Waroux	Planète-A	Belgium
33029	52	3	52	5	Isn't this table repeated?	accepted: duplication of table will be avoided in revised text	Peter Levi	International Energy Agency	France
38577	52	3	52	5	This is a repeat of Table 11.2. If used here, please see my comments above about Table 11.2. Wherever it is used, be sure to label the Table as "for the EU" or "for Europe".	accepted: duplication of table will be avoided in revised text	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
12347	52	4	52	9	Table 11.15. CCS seems to have been left out as a mitigation option? Ref what is shown in Figure 11.13. In addition there seems to be information available on "new industrial processes, circular economy and CCS components in different proportions allowing for the transition to net-zero industrial emission" in the same study as the Table is made from. This is based on the statement from line 6-9 on the same side. Please consider to include similar information in the Table if possible and apropriate.	accepted: availability of specific information will be checked	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
8947	52	12	52	12	Please also state the baseline costs if this comparison is to be included.	rejected: cost differences are calculated against the baseline	Johannes Morfeldt	Chalmers University of Technology	Sweden
25229	52		52		Table 11.5 and associated analysis is already presented earlier in the chapter (see Table 11.2). Delete repetition	accepted: duplication of table will be avoided in revised text	Eleni Kaditi	Organization of the Petroleum Exporting Countries (OPEC)	Austria
20699	52	6	53	19	4 paragraphs in page 52-53 are identical with page 33 (line 6 to 46). So please consider to revise this.	accepted: duplication of table will be avoided in revised text	JUNGYU PARK	International Energy Agency	France
38579	52	6	53	19	Shouldn't this cost information be placed in Section 11.4.1.5 (page 43, line 33)? Also, this information seems to all be for Europe. It would be better if you could include some information for other regions/economies of the world.	accepted: it will be checked if information of comparable number is available for other regions	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
38581	52	6	53	19	What are the costs associated with energy efficiency measures? If energy efficiency and BAT deployment potential is 42% of the B2DS scenario, for example, why are the costs for these not included in this discussion? Please add information on the costs of energy efficiency options.	rejected: aim of this paragraph is not to have a cmprehensive dicussion of abatement costs (for this see earlier parts of the chapter), but to particulalry focus on the three relevant mid- to long-terrm options: industrial processes, circular economy and CCS components in different proportions	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
44871	52	20	53	2	Repeat	rejected: comment unclear	Véronique Waroux	Planète-A	Belgium
12397	52	13			Table 11.4 CCS for cement is not included in the table, even though this was a major solution for cement in the text.	Noted thank you	Maria Malene Kvalevåg	Norwegian Environment Agency	Norway
13297	53	3	53	7	An increased cost for production of 20% or (much) more for a steel producer with already low margins, competing globally. Unless carbon free steel would be priced at a premium on the market the first movers are likely to go out of business.	accepted: text will be revised accordingly	Asa Ekdahl	world steel association	Belgium
44873	53	9	53	19	Repeat in part	accepted: text will be revised accordingly	Véronique Waroux	Planète-A	Belgium
2239	53	35	53	35	Please, after "...improvement." add: "The type of cement in the concrete mix design could improve the potential carbon dioxide uptake of the concrete structure (Sanjuán et al. 2019). For instance, Blast-Furnace Slag Portland cements carbonate more than other types of Portland cements (Andrade and Sanjuán 2018)." References: 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 Andrade C & Sanjuán (2018). Updating Carbon Storage Capacity of Spanish Cements. Sustainability, Volume 10, Issue 12, 4806, pp. 1-15. https://doi.org/10.3390/su10124806	Thanks. Future BF slag availability noted	Miguel Angel Sanjuán	Technical University of Madrid	Spain

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12551	53	35	53	35	Please, after "…improvement." add: "The type of cement in the concrete mix design could improve the potential carbon dioxide uptake of the concrete structure (Sanjuán et al. 2020; Sanjuán et al. 2019; Andrade and Sanjuán (2018)." 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 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 Andrade C & Sanjuán MA (2018). Updating Carbon Storage Capacity of Spanish Cements. Sustainability, Volume 10, Issue 12, 4806, pp. 1-15. https://doi.org/10.3390/su10124806	See previous comment	MORA PERIS PEDRO	Profesor Titular de Universidad de la ETSI Minas y Energía de la Universidad Politécnica de Madrid	Spain
36387	53	39	53	41	Limitation of the resource of woods need to be considered when substition with other materials are discussed.	Will menton it.	Shigetaka Seki	Consumer Product Safery Association	Japan
2237	53	42	53	42	It would neccesary to add a reference. Currently, high-rise buildings (with more than ten floors) are made with steel or reinforced concrete.	Will add references.	Miguel Angel Sanjuán	Technical University of Madrid	Spain
12549	53	42	53	42	Please, add a reference after "High-rise buildings". Currently, high-rise buildings (with more than ten floors) are made with steel or steel reinforced concrete.	Will add references.	MORA PERIS PEDRO	Profesor Titular de Universidad de la ETSI Minas y Energía de la Universidad Politécnica de Madrid	Spain
2235	53	43	53	43	Please, add in line 43: "RISCAuthority required a report to explore the impact that lightweight timber frame (LTF) buildings might have in the UK, as a future dominant building method, based upon current UK statistics and historic US experience. RISCAuthority membership comprises a group of UK insurers that actively support a number of expert working groups developing and promulgating best practice for the protection of people, property, business and the environment from loss due to fire and other risks. They realised that when comparing UK and US statistics, it is critical to bear in mind that the controls in place to limit the size of LTF buildings in the USA are considerably more stringent than in the UK (The Fire Protection Association 2011), but, even so, they reported a significant number of civilian injuries (194) and fatalities (24) sustained during large loss fires in the United States (2003-2008). In addition, The Building Research Establishment (BRE) proposed to increase the period of fire resistance of existing timber floors where there is an alteration, extension or material change of use of a timber building. It discusses the addition of protection to the underside of the ceiling, over the floor boarding and between the joists, and the problems of improving fire resistance when the joists are exposed to view from below (The Building Research Establishment 2008)." The Fire Protection Association, 2011. Design and Management Fire in timber frame buildings. A review of fire statistics from the UK and the USA. BDM14, First published 2011. Version 01. 2011 © The Fire Protection Association on behalf of RISCAuthority. Fire Protection Association London Road, Moreton in Marsh Gloucestershire GL56 0RH, UK. The Building Research Establishment, BRE 2008. DIG 208 Increasing the fire resistance of existing timber floors. IHS BRE Press. The Capitol Building. Bracknell. RG12 8FZ.UK. ISBN 0851253598. http://cfpa-e.eu/wp-content/uploads/2019/06/Article-2-from-Jim-G.pdf BRE 2008 https://www.thenbs.com/PublicationIndex/documents/details?Pub=BRE&DocID=14527	Will mention it.	Miguel Angel Sanjuán	Technical University of Madrid	Spain
12547	53	43	53	43	Please, add: " In contrast, transition to Cross Laminated Timber (CLT) will be difficult in dry climate areas such as southwestern United States and northern Mexico; Argentina; north Africa; south Africa; south Europe; central part of Australia; Western North America (Great Basin, Columbia Plateau, Great Plains); Eurasian interior, from steppes of eastern Europe to the Gobi Desert and North China. Only areas with a humid climate with forests would perform such transition. Also, it should be taken into account that fire risk is increased with associated the social (lower durability than reinforced concrete buildings), economic (high cost) and environmental (carbon dioxide, organic among other emissions) consequences (The Building Research Establishment 2008; (The Fire Protection Association 2011). The Building Research Establishment, BRE 2008. DIG 208 Increasing the fire resistance of existing timber floors. IHS BRE Press. The Capitol Building. Bracknell. RG12 8FZ.UK. ISBN 0851253598. http://cfpa-e.eu/wp-content/uploads/2019/06/Article-2-from-Jim-G.pdf BRE 2008 https://www.thenbs.com/PublicationIndex/documents/details?Pub=BRE&DocID=14527 The Fire Protection Association, 2011. Design and Management Fire in timber frame buildings. A review of fire statistics from the UK and the USA. BDM14, First published 2011. Version 01. 2011 © The Fire Protection Association on behalf of RISCAuthority. Fire Protection Association London Road, Moreton in Marsh Gloucestershire GL56 0RH, UK.	Will mention it.	MORA PERIS PEDRO	Profesor Titular de Universidad de la ETSI Minas y Energía de la Universidad Politécnica de Madrid	Spain
16337	53	21			In Section 11.4.3 Cross sectorial interactions, consider adding a subsection describing environmental pressure on global militaries and their industrial practices, as a parallel to the subsection that describes environmental pressure on industry, for clarity.	Interesting viewpoints. Will check data availability.	Daniel Helman	College of Micronesia-FSM	Micronesia, Federated States of
40277	54	1	54	19	could also cover that industrial waste heat can also be used within industries and shared with other industries - see industrial energy/heat cascading and industrial symbiosis e.g. https://sustainabledevelopment.un.org/content/documents/635486-Kusch-Industrial%20symbiosis_powerful%20mechanisms%20for%20sustainable%20use%20of%20environmental%20resources.pdf ; https://www.ellenmacarthurfoundation.org/case-studies/effective-industrial-symbiosis	Already included. But will consider if the link can be included.	Vida Rozite	International Energy Agency	France
45093	54	1	54	19	The exchange of waste heat between industry and urban areas is discussed in this section. Additional referral can be made for possibilities of circular economy approaches between the industry and urban areas. Other references may include those that are reviewed in Chapter 8 also in support of Table 11.17. The section heading may be updated.	Noted, already in a later section	Siir Kilkis	The Scientific and Technological Research Council of Turkey	Turkey
8949	54	2	54	19	Using waste heat for district heating purposes is important. It's done to large extent in Sweden, to add to the list of examples in the paragraph. However, the paragraph, titled industry and building sector, lacks other aspects of the interlinkages between manufacturing industries and the building sector. This includes supply chain integration to produce energy efficient buildings, promote low-carbon concrete etc.	Already included. Low-carbon concrete is in cement section.	Johannes Morfeldt	Chalmers University of Technology	Sweden

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
40279	54	28	54	28	e.g. Shoreh, M.H. (2016) A survey of industrial applications of Demand Response, Electric Power Systems Research https://www.sciencedirect.com/science/article/pii/S0378779616302632	Thanks. Will check it.	Vida Rozite	International Energy Agency	France
40283	54	28	56	37	https://www.sciencedirect.com/science/article/pii/S0378779616302632	Same as above.	Vida Rozite	International Energy Agency	France
8953	55	27	55	27	The Paris Agreement went into force already in 2016, but the NDCs (the national contributions to meeting the target), as well as reporting requirements generally start from 2020. See: https://unfccc.int/process-and-meetings/the-paris-agreement/what-is-the-paris-agreement	This has been clarified under 11.4.4 to avoid ambiguity	Johannes Morfeldt	Chalmers University of Technology	Sweden
25231	55	27	55	35	Reformulate the subject sentences to avoid repetitions	Done	Eleni Kaditi	Organization of the Petroleum Exporting Countries (OPEC)	Austria
44875	55	27	55	35	Repeat over 2 consecutive paragraphs	Corrected	Véronique Waroux	Planète-A	Belgium
8955	55	34	55	34	All countries already have announced their NDCs through publishing their intended NDCs before the Paris COP in 2015. They then had to present their final NDC for the period starting in 2020 at the same time as ratifying the Paris Agreement. With that said, they will have to update their NDCs continuously since they are valid for a limited time period (5 or 10 years).	This has been clarified under 11.4.4	Johannes Morfeldt	Chalmers University of Technology	Sweden
25233	55	14	56	23	Section 11.4.4 should refer to adverse impacts of response measures to climate change, and their potential effects on sustainable development, as well as to the need of taking into account national circumstances and priorities	A sentence that points to raise caution about potential adverse effect or risk of ambitious climate targets for SDGs has been added to 11.4.4. This is supported relevant reference.	Eleni Kaditi	Organization of the Petroleum Exporting Countries (OPEC)	Austria
29137	55	14	56	23	Some of this is addressed in chapters 3,4 and 17. Perhaps this might better fit in the other chapters as this is not industry specific?	Industry-specific examples have now been added to make it more relevant to the chapter.	Minal Pathak	Ahmedabad University	India
8951	55	15	56	23	How does this section relate to the chapter (that focuses on Industry)? It also includes several mistakes and makes it sound like the issue of linkages between sustainable development and the climate targets of the Paris agreement have not been studied at great extent. This was a large part of the analysis presented in the IPCC Special Report on 1.5 C Global Warming published in 2018. Thus, this section needs to be updated/rewritten. Or perhaps moved to another chapter.	The aim of the subsection is to highlight the role of mitigation options in the industrial sector to SDGs. As such, some industry specific examples from different countries has been cited.	Johannes Morfeldt	Chalmers University of Technology	Sweden
36389	55	14	76		Many of the discussions in this chapter appear to be better placed in other chapters. As comment No1, this chapter should focus on the the issues specific to industrial input and output, the direct (or significant) spillovers (or impact in the process of use, discard, recycle and so on), or specific influences by specific policy and other measures to avoid duplication and to deepen the analysis in this chapter.	Thanks, point well taken	Shigetaka Seki	Consumer Product Safery Association	Japan
11391	56	19	56	19	'Provided by the' may be replaced by ' revealed through the '	The change has been implemented	PINAKI SARKAR	CSIR-CENTRAL INSTITUTE OF MINING AND FUEL RESEARCH	India
12787	56	25	56	35	The paper of Forzieri et al. (2018) shows the impact of 7 climate change driven natural hazards on critical infrastructures (including industries) 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 industries. GEC Article: "Escalating impacts of climate extremes on critical infrastructures in Europe" https://www.sciencedirect.com/science/article/pii/S0959378017304077	Good suggestion. Will adjust section and cite reference	antoine leblois	INRA	France
40281	56	37	56	37	could consider multiple benefits e.g. https://www.mbenefits.eu/ ; https://www.iea.org/reports/multiple-benefits-of-energy-efficiency could fit in section 11.5.4.3 - perhaps including some quantifications or examples	Multiple benefits of energy efficiency should be refered to in 11.3.4 or in 11.5.4	Vida Rozite	International Energy Agency	France
29133	56	41	56	41	Please check the title- not sure if stkaeholders fits in. Perhaps looking at barriers and opportunities in one sub-section and Benefits and trade-offs with SDGs as a separate sub-section might work	Indeed, the three firs paragraph of this section should have been in the previous section called 11.5.1 Infrastructure, fixed capital lock-ins + future infrastructure	Minal Pathak	Ahmedabad University	India
25235	56	41	57	41	Section 11.5.2 should refer to special circumstances and capabilities of developing countries, as well as the barriers for specific economies to diversify their economies and ensure just work transition	Rejected. Differentiation of countries' capabilities to transition is already address in the text in the context of material demand and current stock	Eleni Kaditi	Organization of the Petroleum Exporting Countries (OPEC)	Austria
16339	56	37			In Section 11.5 Barriers, opportunities and co-benefits for stakeholders, consider adding a subsection that highlights the barriers that industry related to global militaries poses, and also the opportunities for transformation that global militaries could make in leading industrial transformation. Alternately, this information could be included in the relevant subsections (i.e. 11.5.2 and 11.5.4) for clarity and accuracy.	We find it very difficult to elaborate this point in the very limited space we have, but will look for a way to perhaps mention it.	Daniel Helman	College of Micronesia-FSM	Micronesia, Federated States of
18873	57	13	57	14	Please check the following study for further information on direct and indirect emissions in China. Referecence: Ma, N., Li, H., Tang, R., Dong, D., Shi, J., & Wang, Z. (2019). Structural analysis of indirect carbon emissions embodied in intermediate input between Chinese sectors: a complex network approach. Environmental Science and Pollution Research, 26(17), 17591-17607.	Rejected, the indirect emissions referred in the IPCC chapter text is related to emissions from electricity and heat consumption in the industry sector. In the article cited, indirect emissions refer to embodied emissions from intermediate input in the production of products accross different industry subsectors. Since we are not detailing subsector emissions in this section, the reference is not necessary.	Etem Karakaya	Independent researcher, former Profesor,fired with the decree of law since 2016	Turkey

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
28719	57	15	57	20	It is important to note that in some cases where the production capacity is not expected to grow in the future, from a GHG mitigation point of view it might make more sense to extend the lifetime of existing (less efficient) facilities as long as possible before switching to truly low-carbon technologies (if production capacity is to remain) rather than hastily investing in BAT technologies in a shorter term. Suggested additional reference: Kuramochi, T., 2017. Assessment of CO 2 emissions pathways for the Japanese iron and steel industry towards 2030 with consideration of process capacities and operational constraints to flexibly adapt to a range of production levels 147, 668–680. https://doi.org/10.1016/j.jclepro.2017.01.087	Noted thank you, we will consider the paper	Takeshi Kuramochi	NewClimate Institute	Germany
8957	57	21	57	25	Some might argue that carbon pricing in itself would be a sufficient instrument, especially combined with a cap on total emissions (i.e. emissions trading system). Please include why additional incentives are needed, preferably backed up by further reasoning in policy focused papers since this will is a contentious issue within policy design. Also, it would be useful to include a discssion on the intended incentives and what sort of policy instruments have which benefits.	Partially accepted.We agree and we already addressed these issues in the next session on policies	Johannes Morfeldt	Chalmers University of Technology	Sweden
44877	57	23	57	23	delete a "can both"	Editorial . Editorial error corrected in the second draft	Véronique Waroux	Planète-A	Belgium
40243	57	31	57	31	the substitution of cementitious materials may involve low financial costs but in any case negligibles. I suggest to avoid this word	Accepted. Will remove the example in brackets	Ana Ines Fernandez	University of Barcelona	Spain
9763	57	31	57	41	As mentioned in the report, a policy such as giving incentive to the supply of low-carbon intermediate goods to companies that produce low-carbon final products, would be important for emission reduction in the material producing industries.	Thank you for this comment. As mentioned in the coment this is already addressed later in the policy section.	JAE YOON LEE	Korea Institute for Industrial Economics and Trade(KIET)	Republic of Korea
25237	57	43	58	42	Section 11.5.3 should refer to policies aiming for economic diversification, as well as trade-related policies and incentives provided for R&D and innovation	R&D and tariffs are already mentioned and we do not have the space to list every policy that can be mentioned in the context of industrial policy	Eleni Kaditi	Organization of the Petroleum Exporting Countries (OPEC)	Austria
20701	57	23			2 words "can both" are repeated.	Editorial . Editorial error corrected in the second draft	JUNGYU PARK	International Energy Agency	France
8959	58	12	58	14	Unclear. Is it an important aspect that is currently included in industrial policy in general or is it something that should be included? I assume that it's the latter given the following paragraph.	We will clarify that this is future need	Johannes Morfeldt	Chalmers University of Technology	Sweden
39029	58	28	58	33	Please split the term CCUS into CCS and CCU in line 29. The following information should be added: 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). (REFERENCES: Levänen and Hukkinen, 2019, Global Sustainability, 2, e25/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./ Zhu, 2019, Clean Energy, Vol. 3, No. 2, 85–100./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.)	We agree and will split CCU and CCS. 11.5.3 is not the right place for elaborating on CCU/CCS but the points made will be considered for 11.3.6	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
8961	58	44	61	33	This is a good and interesting section on co-benefits, but what about the trade-offs of mitigation strategies and the SDGs. Do they exist and for which type of measure?	A statement on this with reference has been added to the introduction to the section on Co-benefits of Mitigation Strategies and SDGs	Johannes Morfeldt	Chalmers University of Technology	Sweden
25241	58	44	61	33	Section 11.5.4 to further elaborate on risks, synergies and negative impacts throughout the different sub-sections	Done	Eleni Kaditi	Organization of the Petroleum Exporting Countries (OPEC)	Austria
46743	58	44	61	33	Review-based conclusions regarding co-benefits can be found in: Mikael Karlsson, Eva Alfredsson & Nils Westling (2020) Climate policy co-benefits: a review, Climate Policy, DOI: 10.1080/14693062.2020.1724070.	This is a very good suggested reference. The paper has been cited when introducing Co-benefits of Mitigation Strategies and SDGs	Mikael Karlsson	KTH Royal Institute of Technology	Sweden
44959	59		59		Figure 11.15: Use higher resolution so that reader can read the small icons.	Accepted, this will be corrected for in the final stages of publication	Andreas Schroeder	International Energy Agency IEA	France
40285	60	12	60	12	consider revising heading 11.5.4.2 SDGs co-Benefits through Circular Economy and Industrial Waste - reads as benefits trhough waste	The word "through" has been changed to "from"	Vida Rozite	International Energy Agency	France
11393	60	22	60	22	'an d' should be replaced by 'and'	Change has been effected	PINAKI SARKAR	CSIR-CENTRAL INSTITUTE OF MINING AND FUEL RESEARCH	India
40245	60	22	60	22	growth and instead of growth an d	Same as above; change has been implemented	Ana Ines Fernandez	University of Barcelona	Spain
44879	60	22	60	22	correct "and"	Same as above; change has been implemented	Véronique Waroux	Planète-A	Belgium
40247	60	37	60	37	Whiles proponents of the benefits and co-benefits instead of benefits of the co-benefits	Change has been implemented	Ana Ines Fernandez	University of Barcelona	Spain

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
27485	60	38	60	40	There is no source to back up the statement that 'some have cautioned againts the idea of designing waste out of the circular economy'. Since this is one of the most central concepts within the Circular Economy (Pires, 2019; Singh et al 2016), it's unacceptable that this statement is included without a source to allow a followed-up discussion. Pires, Ana, and Graça Martinho. "Waste hierarchy index for circular economy in waste management." Waste Management 95 (2019): 298-305. Singh, Jagdeep, and Isabel Ordoñez. "Resource recovery from post-consumer waste: important lessons for the upcoming circular economy." Journal of Cleaner Production 134 (2016): 342-353.	The sentence has been removed.	Mariel Vilella Casaus	Zero Waste Europe	United Kingdom (of Great Britain and Northern Ireland)
40287	61	9	60	10	consider revising as reads "Electricity…has provided a flexible system to pursue electrification"	Sententenc has been revised to ensure clarity.	Vida Rozite	International Energy Agency	France
8963	61	9	61	14	Lacking sources and listing which SDGs are being co-benefited by electrification and fuel-switching.	The SDGs have been specified and source provided.	Johannes Morfeldt	Chalmers University of Technology	Sweden
39031	61	16	61	34	Again in this section CCUS should be splitted into CCS and CCU and both concepts should be discussed separately. Here some extra input: 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 (e.g.Ampelli et al., 2015, Bruhn et al., 2016, Krey et al., 2019). The existing literature shows that the current co-benefits of CCU are numerous (VITO, 2018). Here are some examples, 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 (REFERENCES: VITO, 2018 (Miet van Dael), Market Study Report CCU, Flemish Institute for Technological Research NV./Bruhn et al., 2016, Environmental Science & Policy, 60, 38–43./ Krey et al., 2019, Energy, 172, 1254-1267/ 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.)	As suggested, CCS and CCU have now been seperated and addessed differently in relation to their co-benefits to SDGs.	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
25239	61	22	61	23	Delete "and 'greening' of fossil fuel energy systems"	Accepted	Eleni Kaditi	Organization of the Petroleum Exporting Countries (OPEC)	Austria
13299	61	40	61	40	low carbon	Not sure what is the comment about	Asa Ekdahl	world steel association	Belgium
26123	61	45	62	6	The importance of policy packages is also stressed in Chapter 13 (section 13.6 Policy mixes and governance). It would be very helpful to have examples of such climate mitigation policy packages targeting industry sector in Chapter 11. They could be referenced in Chapter 13 (e.g. Table 13.5 Enablers and barriers for policy led sector transitions)	Partially accepted. Thank you for your comments. Policy package is further addressed in the next section and yes, we are coordinating with Chapter 13 to provide examples that will be refered in their Chapter.	Mykola Shlapak	N/A	Ukraine
36391	61		63		Discussion here is too general and should be integrated in other appropriate chapter.	point well taken	Shigetaka Seki	Consumer Product Safery Association	Japan
35009	61		73		Policy approaches could vary across sectors. Please write policy approaches for resource and energy intensive sectors identified.	Accept	Pramod K Singh	Institute of Rural Management Anand	India
35011	61		73		How could regenerative and conscious capitalism could help in industrial transition?	Reject. Discussion is beyond Ch 11	Pramod K Singh	Institute of Rural Management Anand	India
42075	61	6			The continuous efforts done by the European Commission with regard to WEEE (Waste Electrical & Electronic Equipment) since the first directive (Directive 2002/96/EC) entered into force in 2003 should be acknowledged, as well (https://ec.europa.eu/environment/waste/weee/index_en.htm)	Reject beyond scope of Ch11	Francisco Javier Hurtado Albir	European Patent Office	Germany
16341	61	35			In Section 11.6 Policy approaches and strategies, consider adding a subsection that describes the potential of militaries globally to shape industrial transformation via policy related to the manufacture of their equipment, arms and other supplies.	Interesting but rejected. Beyond scope and no litterature	Daniel Helman	College of Micronesia-FSM	Micronesia, Federated States of
25243	63		63		Figure 11.17: do not use undefined terms such as "green market"	Accepted. We will refer more specifically to low carbon market.	Eleni Kaditi	Organization of the Petroleum Exporting Countries (OPEC)	Austria
44881	64	20	64	45	The importance of training and education should be added.	Accepted. Thank you, acknowledged, and incorporated in the rewrite.	Véronique Waroux	Planète-A	Belgium

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
28021	64	20	64	48	These studies offer country-by-country roadmaps to transition the industrial sector along with all other energy sectors to 100% wind, water, and solar power for 143 and 139 countries, respectively: 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, 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. Please include these studies.	Accepted. Thanks, reviewed and incorporated where appropriate.	Mark Jacobson	Stanford University	United States of America
25245	64	36	64	36	Delete "reinterpretation of"	Done	Eleni Kaditi	Organization of the Petroleum Exporting Countries (OPEC)	Austria
36393	64		65	9	It is true that various types of policy measures should be adopted to meet the ambitious target, however, the reason why such approach is difficult (and thus impractical in many cases) needs to be discussed. The case of NEDO is, in this regard, misleading because it includes practical policy measures only.	Acknowledge, and incorporated in the rewrite.	Shigetaka Seki	Consumer Product Safery Association	Japan
10951	64	11	66	34	Section 11.6.2 on carbon prices and carbon markets is relatively brief in relation to their importance as mechanisms for reducing industrial emissions and would benefit from further analysis of some of the issues mentioned in the paragraph on real-world implementation. The analysis of BCAs is informative on options that governments might choose but, given that the likely need for these to pass WTO scrutiny is raised, further analysis of this in relation to California's BCAs on electricity imports (and in the future, cement) in relation to merited. Issues where further analysis is needed include the extent and ways in which energy intensive industries are allowed exemptions and free allowances to shield them from price increases. This statement is too broad and does not take into account examples where these are accompanied by other requirements (such as with the UK Climate Change Agreements). Some examples of the way in which these forms of conditional shielding are implemented would be beneficial for revealing policy options available. Social equity issues and resistance also need further elaboration to explore in more details the reasons for these difficulties, the effects produced on policy and how they have been managed. Analysis of the Australian failed Carbon Pricing Mechanism can be found in: Bailey, I. and Jackson Inderberg, T.H. (2017) Australia: domestic politics, diffusion and emissions trading design as a technical and political project, in Wettestad, J. and Gulbrandsen, L. (eds) The Evolution of Carbon Markets: Design and Diffusion, 124-144 and doubtless other examples exist. In overall terms, the section would provide greater benefit to policy makers with further discussion of the issues, over and above carbon leakage, that have hindered carbon pricing and carbon markets.	Accepted. Comments were useful and text was added based on the comments, notably the voluntary agreement, the reference on political context of carbon price and California's scheme. However, due to the limit of words allowed, we had to limit the descriptions but references are provided.	Ian Bailey	University of Plymouth	United Kingdom (of Great Britain and Northern Ireland)
44885	65	15	65	17	Explain IAM modelling	Rejected because the text was deleted and the reference to IAM models became irrelevant.	Véronique Waroux	Planète-A	Belgium
1103	65	27	65	29	To be effective a pricing system must impose a price on marginal emissions. A free allocation imposes a price on marginal emissions while minimizing the financial cost to the emitter. A price on all emissions has the same marginal price and hence the same impact on emissions but impses a much larger financial cost on the emitter. The Canadian tax (p. 66 lines 28-30) does the same; it imposes a tax on marginal emissions while minimizing the financial burden that would be created by taxing all emissions.	Partially accepted. We added the effect that provisions for EITE can have on the price of marginal emissions but we distinguished this effect with internalizing the full cost of externatilities that can better drive innovation of current installed capacity	Erik Haites	Margaree Consultants Inc.	Canada
1105	65	30	65	45	This discussion could focus more on industry by distinguishing between carbon taxes and emissions trading. Most pricing policies for industry are trading systems (Canada is an exception) while taxes mostly apply to retail sales of fossil fuels. (Postic, Sébastien and Clément Métivier, 2019. Global Carbon Account 2019, Institute for Climate Economics (IC4E), Paris.) Assessments of the performance of existing taxes and trading systems are provided by Haites, Erik, Duan Maosheng, Kelly Sims Gallagher, Sharon Mascher, Easwaran Narassimhan, Kenneth R. Richards, and Masayo Wakabayashi, 2018. Experience with Carbon Taxes and Greenhouse Gas Emissions Trading Systems, Duke Environmental Law and Policy Forum, Fall 2018, 29(1), 109-182. Available at: https://scholarship.law.duke.edu/delpf/vol29/iss1/ and Metcalf, Gilbert, 2019. On the Economics of a Carbon Tax for the United States. Brookings Papers on Economic Activity, Spring 2019, 405-484. https://www.brookings.edu/bpea/search/	Accepted. Most references were added and the disctinctions was made to the extend possible knowing that number of word are limited	Erik Haites	Margaree Consultants Inc.	Canada
13697	65	30	65	45	More could be developed from the commentary in this section, particularly as carbon pricing and the allocation of carbon credits are highly open to political decision-making and lobbying from industry (e.g. to add more carbon credits into a market where these have been bought up and removed by enterprises / organisations established for this purpose).	Partially accepted. Text was added to reflect the political circonstances of free allowances. However, additional details on allocating more credits was not added as we have to limit text and this is already addressed in Chapter 13	Keith Baker	Built Environment Asset Management (BEAM) Centre, Glasgow Caledonian University	United Kingdom (of Great Britain and Northern Ireland)
39895	65	30	65	45	The entire section is biased against carbon pricing and emissions trading systems and needs to be rewritten. Key references for the effectiveness of these instruments are Haites (2018), Haites et al. (2018), Narassimhan et al. (2018). Please align your assessment with the assessment in Chapter 13 and past assessments of carbon pricing / emissions trading in AR 5. New references: Erik Haites (2018a) Carbon taxes and greenhouse gas emissions trading systems: what have we learned?, Climate Policy, 18:8, 955-966; Erik Haites et al. Experience with Carbon Taxes and Greenhouse Gas Emissions Trading Systems, 29 Duke Environmental Law & Policy Forum 109-182 (2018); Easwaran Narassimhan, Kelly S. Gallagher, Stefan Koester & Julio Rivera Alejo (2018) Carbon pricing in practice: a review of existing emissions trading systems, Climate Policy, 18:8, 967-991	Partially accepted. Text was added to provide a more positive description of the effectivenesss of cap and trade schemes as the references provided suggest. However, references to literature describing the limits of cap and trade and their applications in real world were kept as they are based on valid analysis. We believe that the text provides a balanced overview of the litteratrure on the topic, needed for the possible application of these schemes to achieve Paris agreement.	Axel Michaelowa	University of Zurich	Switzerland

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
43395	65	30	65	45	This is clearly written with a very strong preconception against the role of carbon pricing and carbon markets in international climate policy without adequate referencing. There are also fundamental departures in assessment compared to chapter 13 as well as generally speaking IPCC assessment on the matter including notably AR 5. Recent publications that ought to be reflected include Haites (2018a) Carbon taxes and greenhouse gas emissions trading systems: what have we learned?, Climate Policy, 18:8, 955-966; Haites et al. Experience with Carbon Taxes and Greenhouse Gas Emissions Trading Systems, 29 Duke Environmental Law & Policy Forum 109-182 (2018); Narassimhan, E., Gallagher, K. S., Koester, S., & Alejo, J. R. (2018). Carbon pricing in practice: A review of existing emissions trading systems. Climate Policy, 18(8), 967-991.	Accepted, references and main findings from references suggested have been added	Matthias Honegger	Perspectives Climate Research gGmbH	Germany
25247	65	11	66	34	Section 11.6.2 should refer to the need of non-discriminatory policies towards specific fuels, and the flexibility needed for developing countries when introducing carbon prices	Accepted, revised	Eleni Kaditi	Organization of the Petroleum Exporting Countries (OPEC)	Austria
43139	65	11	66	34	The authors should consider harmonizing the assessment terminology used in the policy assessment with the criteria developed by chapter 13 (refer to table 13.3) to ensure a report wide consistency in policy assessment.	Accepted, revised	Parth Bhatia	Centre for Policy Research, New Delhi	India
44883	65	11	66	34	The "ideal" curve of the price cu Carbon should be added (high at the beginning of the application)	Rejected, this is already included "Carbon pricing is also criticized for prioritizing short-term, low-cost options with a gradual increase of the carbon price in the long run, while long-term investments require a reverse trajectory that calls for high "investment signaling" carbon prices now that gradually decline in the future (Rosenbloom et al., 2020; Stiglitz, 2019; Vogt-Schilb et al., 2018)."	Véronique Waroux	Planète-A	Belgium
1107	65	46	66	6	The revenue redistribution is of limited relevance for industry; the uses cited are almost all outside the industrial sector. Instead industry receives free allowances or tax benefits as noted in the previous paragraph and in the description of Canada's tax. As an aside, that revenue collected has increased rapidly over the past few years. Postic, Sébastien and Clément Métivier, 2019. Global Carbon Account 2019, Institute for Climate Economics (IC4E), Paris.	Accepted. One example of allocation to the industry was added but general comments about the fact that industry already receives free allowance so the use of revenue for their transition is limited was included in the text	Erik Haites	Margaree Consultants Inc.	Canada
39893	65	11			Section 11.6.2: Insert paragraph on how industry benefitted from international carbon market mechanisms like the Clean Development Mechanism in bringing compliance costs for the EU ETS down and generating revenues for industries in many developing countries. See the evidence collected in Michaelowa et al. (2019). Michaelowa, Axel; Shishlov, Igor; Brescia, Dario 2019 Evolution of international carbon markets: lessons for the Paris Agreement, in: WIREs Climate Change, 10, e613, DOI: 10.1002/wcc.613	Rejected. Industry represents a very small share of offset programs (~3% of CDM, see "Assessing the impact of the clean development mechanism", http://www.cdmpolicydialogue.org/research/1030_impact.pdf). Moreover, CDM and offset programs are already addressed in Chapter 13 where the reference suggested is provided.	Axel Michaelowa	University of Zurich	Switzerland
20703	65	28			As USD 40 is related to carbon taxes prices, suggest to include complete unit of CO2 amount such as USD 40 tCO2-eq^-1.	Accepted, thank you.	JUNGYU PARK	International Energy Agency	France
1109	66	7	66	27	Chapter 13 has a box on leakage that provides a more comprehensive review of the literature. The text notes, correctly, that existing trading systems have provided free allowances to protect industries prone to leakage. Then it discusses alternatives -- BCA and consumption pricing -- that are almost never used. The literature indicates that free allocation does the job effectively, so there is little reason to discuss these alternatives that are not used.	Noted, reference to Chapter 13 was made	Erik Haites	Margaree Consultants Inc.	Canada
44887	66	20	66	20	Explain WTO	Accepted, text revised	Véronique Waroux	Planète-A	Belgium
2243	66	40	66	40	I recommend to delete "...or concrete...". The reason is because the potential of re-circularity of concrete is high. Currently, concrete fines will be standardized as a new cement constituent in the European standardization CEN/TC 51 "cements and construction limes".	Partially accepted. Text revised to include the fact that the potential is high but the value remains low today	Miguel Angel Sanjuán	Technical University of Madrid	Spain
12553	66	40	66	40	Please, delete "...or concrete...". The potential of re-circularity of concrete is high. C	Partially accepted. Text revised to include the fact that the potential is high but the value remains low today	MORA PERIS PEDRO	Profesor Titular de Universidad de la ETSI Minas y Energía de la Universidad Politécnica de Madrid	Spain
2241	66	41	66	41	Year of te reference is missing.	Accepted	Miguel Angel Sanjuán	Technical University of Madrid	Spain
43141	66	33	68	2	This section would benefit from a box providing a descriptive narrative around a "success story" for achieving material efficiency through a circular economy approach	Thank you for this comment. We will consider in SOD	Parth Bhatia	Centre for Policy Research, New Delhi	India
8965	66	37	68	2	This section would benefit from more clearly stating the relation to climate change mitigation. The chapter has shown that circular economy and materials efficiency as measures can have significant potential for reducing emissions, but this section focuses on some waste flows that are not so important from a climate change mitigation perspective and provides examples of policies mainly designed for other purposes. This is fine in general if no other examples can be found, but then the linkage to climate change mitigation needs to be more clearly discussed in the section.	Accepted. The linkage to climate change mitigation will be more clearly described.	Johannes Morfeldt	Chalmers University of Technology	Sweden

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
27489	67	6	67	7	Need editing to reflect this is an estimate of what has happened so far. It's possible that with the introduction of progressive policies aiming to reduce plastic pollution these estimates are constantly evolving, therefore they should not presented as stalled. The source says: "According to recent estimates,18 79% of the plastic waste ever produced now sits in landfills, dumps or in the environment, while about 12% has been incinerated and only 9% has been recycled". UNEP 2018: SINGLE -USE PLASTICS: A Roadmap for Sustainability. 104 pp	Accepted	Mariel Vilella Casaus	Zero Waste Europe	United Kingdom (of Great Britain and Northern Ireland)
44961	67	11	67	11	"Mixed results"- please expand on this interesting finding.	Please refer to reference cited as number of words are limited. Thank you	Andreas Schroeder	International Energy Agency IEA	France
27491	67	23	67	29	This is not the most relevant and updated example of EU policy implementing EPR, which is a central tool in the Circular Economy Package. The text needs to be replaced to show that: "the European Parliament has approved the Circular Economy Package which updates current waste management rules, including new targets for recycling, packaging and landfilling. The new ambitious recycling and landfilling targets will boost the re-use of valuable material in waste and improve the way municipal and packaging waste is managed thus making the circular economy a reality. It further strengthens the "waste hierarchy" by placing prevention, re-use and recycling clearly above landfilling and incineration. The new legislation foresees more use of effective economic instruments and other measures in support of the waste hierarchy. In terms of incentives, producers are given an important role in this transition through extended Producer Responsibility (EPR) schemes – meaning a producer's responsibility for a product is extended to the post-consumer stage of a product's life cycle. The new extended producer responsibility requirements will lead to better performance and governance of these schemes. A mandatory extended producer responsibility scheme has to be established for all packaging by 2025. European Commission, 18th April 2018, New waste rules will make EU global front-runner in waste management and recycling. Retrieved here: https://ec.europa.eu/info/news/new-waste-rules-will-make-eu-global-front-runner-waste-management-and-recycling-2018-apr-18_en	Accepted. The example was removed and replace by a more generic reference on the use of EPR globally	Mariel Vilella Casaus	Zero Waste Europe	United Kingdom (of Great Britain and Northern Ireland)
27493	67	45	67	46	Needs to add the very important EU legislation that has been developed in relation to the EU Circular Economy Action Plan in 2015. The revised legislative framework on waste (Circular Economy Package) entered into force in July 2018. It sets clear targets for reduction of waste and establish an ambitious and credible long-term path for waste management and recycling. Key elements of the revised waste proposal include: A common EU target for recycling 65% of municipal waste by 2035; A common EU target for recycling 70% of packaging waste by 2030; There are also recycling targets for specific packaging materials: Paper and cardboard: 85 % Ferrous metals: 80 % Aluminium: 60 % Glass: 75 % Plastic: 55 % Wood: 30 % A binding landfill target to reduce landfill to maximum of 10% of municipal waste by 2035; Separate collection obligations are strengthened and extended to hazardous household waste (by end 2022), bio-waste (by end 2023), textiles (by end 2025). Minimum requirements are established for extended producer responsibility schemes to improve their governance and cost efficiency. Prevention objectives are significantly reinforced, in particular, requiring Member States to take specific measures to tackle food waste and marine litter as a contribution to achieve EU commitments to the UN SDGs.	Partially accepted. The EU Circular Economy Action Plan is already mentioned in the text. Considering the space limit and the development of circular economy objectives in other regions, only a sentence will be added to summarize the EU new commitments.	Mariel Vilella Casaus	Zero Waste Europe	United Kingdom (of Great Britain and Northern Ireland)
44889	68	15	68	38	Cite Life Cycle Assessment, Carbon Footprint, Ecological Footprint, Bilan Carbone, Environmental Footprint as evaluation methods.	Rejected. LCA methods are already cited in the text and referenced with the corresponding ISO standards. In the paragraph we also aknoweldge that numerous methofds for carbon footprint exist without listing them as the list will be (1) too long and (2) may lack of geographical representativeness	Véronique Waroux	Planète-A	Belgium
36395	68	42	68	43	I suppose that the amount of governent expenditure go to procurement, here, includes that for defense. Did someone analyse how much defence spending could climate friendly by how?	Rejected. This is only infrastructure, The Defense budget is another category in the OECD statistics. Please refer to the source for more details. Thanks	Shigetaka Seki	Consumer Product Safery Association	Japan
25249	68	23	71	10	Do not use terms such as "green products", "green market", "green material procurement", etc.	Accepted . We will use the terminology of "low carbon" to be more specific	Eleni Kaditi	Organization of the Petroleum Exporting Countries (OPEC)	Austria
36397	69	41	70	32	The standards is a policy measure which should be better discussed in other chapter. Here, the influence of such policy to industry input, output should be discussed. For example, higher insulation requirement increase the demand for insulation materials, prefer plastic/wood window frames over metal frames, and so on.	Acepted. We will add a reference and the need to consider trade off between creating new material demand and energy reduction	Shigetaka Seki	Consumer Product Safery Association	Japan
40289	69	45	70	15	see a;so resources published by the Global Alliance for Buildings and Construction and world Green Building Council e.g. https://www.worldgbc.org/embodied-carbon	Accepted. Thank you for the reference.	Vida Rozite	International Energy Agency	France

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
13301	70	35	70	35	IEA quote 10-90% more expensive compared to natural gas	Accepted. We will look for this reference form IEA	Asa Ekdahl	world steel association	Belgium
44963	70	44	70	44	"Contract for Differences" are currently in discussion and in legislative preparation in Germany to incentivise low-carbon production of steel, aluminium, chemicals, etc.. Check Agora Energiewende industry report of 2019.	Accepted. Reference was added. We will also investigate on updates of the proposed law from the German government on CfD.	Andreas Schroeder	International Energy Agency IEA	France
44891	71	3	71	3	"guarantee" or "get accepted"?	Guarantee. Text was added to clarify	Véronique Waroux	Planète-A	Belgium
43143	71	26	71	30	Is there a go-to example technology where the progression through each of these stages is well understood and documented? If so, kindly add a few references to illustrate the point.	Accepted. We will elaborate further and describe an example	Parth Bhatia	Centre for Policy Research, New Delhi	India
14317	71	35	71	37	Correction & addition: "Important areas for basic research and small piloting can be identified since there is are generally a limited set many possible process options for producing basic materials from virgin or recycled feedstock using GHG-free energy or CCUS and CCU (see NAS 2019b, https://doi.org/10.17226/25232; and the research roadmaps from the European large research (formerly flagships) initiatives SUNRISE and Energy-X)"	Accepted	Anastasios Perimenis	CO2 Value Europe (Association) - CCU Offiver	Belgium
36399	71	12	171	30	Please see comment No. 10.	Accepted	Shigetaka Seki	Consumer Product Safery Association	Japan
44893	72	11	72	12	"is well served" with so few examples? Singular or plural?	Accepted. To be addressed, the bigger point is that we don't need to do more R&D, we need to commericialize	Véronique Waroux	Planète-A	Belgium
44895	72	18	72	19	3 examples only. This seems to indicate that we are at a very early stage, contrary to the discourse in this chapter where it is stated that the technologies are known and to be applied.	Partially accepted. The examples given here are exampels that have been demontrated but needs market policy to support their chance to scale up to maintream technologies. This is the beginning of the valley of death. There are many other examples given through the chapter that have a higher TRL and are on teh market.	Véronique Waroux	Planète-A	Belgium
43145	73	1	73	1	The governance section should also address in greater detail the changes needed in policy processes to enable such a fundamental transformation of industrial policymaking.	Accepted. Interesting idea, we'll try to address it in the new version of the chapter.	Parth Bhatia	Centre for Policy Research, New Delhi	India
43147	73	1	73	1	Perhaps the authors could address, through a case study or a comparative case study, some of the major green industrial policy plans studied in literature. In particular, it would be good to understand the context specific governance barriers and the policy design response to overcome the same.	Interesting idea, would take some effort, but interesting.	Parth Bhatia	Centre for Policy Research, New Delhi	India
14319	73	42	73	42	Addition: "and disposal, but some CCU products like fuels and chemicals can benefit from the existing distribution infrastructure".	Partially accepted. WEewill review the CCUS/CCS infrastructure needs and modify as needed	Anastasios Perimenis	CO2 Value Europe (Association) - CCU Offiver	Belgium
25251	73	1	74	30	Section 11.6.6 to consider matters related to developing countries as well, when presenting governance issues	Accepted.	Eleni Kaditi	Organization of the Petroleum Exporting Countries (OPEC)	Austria
42077	73	43			"... capacity requirments IN THE CONTEXT OF CHANGED CLIMATE WICH WILL HAVE A DIRECT IMPACT ON THE INFRASTRUCTURE"	Accepted.	Francisco Javier Hurtado Albir	European Patent Office	Germany
13303	74	2	74	2	Teesside	Accepted.	Asa Ekdahl	world steel association	Belgium
18875	74	35	74	43	comment 6 about material input substitution possibilities with respect to capital, labour and energy could also be mentioned here as knowledge gap. While some more detailed analyses are needed for the possible interactions between factors of production vis a vis to materials, it is also essential to have further research how to substitutite materials with labour and capital, which requires more engineering research.	Agree in principle but difficult to include here (literature and space constraint)	Etem Karakaya	Independent researcher, former Profesor,fired with the decree of law since 2016	Turkey
45095	75	1	75	4	The chapter contains good points of emphasis on transition processes and transformational change. An extra opportunity may be to emphasize how shifts in the industry sector can enable transformations in other sectors and systems based on the exchange of energy and materials and their reduction. This could also support key messages within urban systems. Moreover, the use of waste heat can improve the energy and climate performance of cities, such as discussed based on scenarios for cities in the reference <https://doi.org/10.1016/j.rser.2018.11.006>	Thanks. Sectoral couplings and industrial symbiosis includes this	Siir Kilkis	The Scientific and Technological Research Council of Turkey	Turkey
44897	75	7	75	7	Correct "often"	Thanks	Véronique Waroux	Planète-A	Belgium

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
39033	75	12	75	14	CCUS should be replaced by CCU. 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. 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. (REFERENCES: Kätelhön et al., 2019: Climate change mitigation potential of carbon capture and utilization in the chemical industry, PNAS, 116, 23, 11187-11194/Nocito and Dibenedetto, 2020, Current Opinion in Green and Sustainable Chemistry, 21, 34–43./ Bruhn et al., 2016, Environmental Science & Policy, 60, 38–43./ Arning et al. 2019, Energy Policy, 125, 235–249./EAGHG, 2019b: Exploring Clean Energy Pathways: the role of energy storage, International Energy Agency./ Zhu, 2019, Clean Energy, Vol. 3, No. 2, 85–100.)	Yes, revised	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
46797	75	21	75	23	Cross dependency between economic sectors has been extensively worked with input output tables (IOT). This paragraph should consider these works.	Beyond our scope. Reject	Luis Javier Miguel González	University of Valladolid	Spain
9631	75	1			"A significant shift is needed…to transformational change…" This statement (while correct) strongly downplays the many forces that are aligned against this kind of shift. The paragraph implies that a key barrier is TRL, but other culrtural attitudes within industry are often more substantial than "will the technology work?". In the chemical industry (my area of experience), no company wants to build the first plant using a new apprach when legacy methods that are already demonstrated exist. All of the challenges associated with huge sunk costs and human experience that exist in the electricity sector also apply to industry and should be discussed as a key barrier.	Accept	David Sholl	Georgia Institute of Technology	United States of America
13305	76	1	76	1	The term "hard to abate" relates to the fact that we are not mearly talking about fuel switching but new production processes and that these will mean significant investments. The steel industry also operates at very low margins and is highly internationally traded which reduces the possibilities to pass on costs to customers	Accept	Asa Ekdahl	world steel association	Belgium
11395	76	10	76	21	Note: Support provided by various countries towards Clean energy initiatives which includes the coal cess, based on the principle of 'polluter pays', may be mentioned (for example, in India it was introduced in 2010 and it is being levied on domestic and imported coal) . The cess may accrue to the National Clean Energy and Environment Fund (NCEEF) for various nations, and may be considered to be an effort to tax carbon for its externalities and the accumulated fund out of taxation may serve as a steady source for funding clean energy projects. Actions taken by various countries in line with the implementation and propagation of clean energy mission in industry sector may be mentioned and analyzed in this section.	Thanks. Now mentioned but not possible to elaborate in detail	PINAKI SARKAR	CSIR-CENTRAL INSTITUTE OF MINING AND FUEL RESEARCH	India
39035	76	11	76	21	Please split CCUS into CCS and CCU in this paragraph.	Accept	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
16343	76	23			In FAQ 11.4 What needs to happen for a low carbon industry transition?, consider adding a description of the role global military procurement plays in determining industrial processes for manufacturing goods and materials used by that sector, and the key influence that sector has in determining outcomes.	Beyond scope	Daniel Helman	College of Micronesia-FSM	Micronesia, Federated States of
36369			4	6	The same comment above applies to the introduction. It is true that the adoption of wide range of, and variety of policy options may technically lead to close to net zero emissions in major industrial sectors, however, as discussed later in the chapter, there are difiiculties to take such policies for economic, technical, competitiveness-related, distributional, legal, behavioral and other reasons, many which are not at all easy to address. Such difficulties must be discussed in the executive summary to avoid misleading overly rosy picture in the future.	Accepted	Shigetaka Seki	Consumer Product Safery Association	Japan
6097		19		26	The use of the Resources of the Nurinsal is necessary to be raised with rational and judicious technical criteria, which allow to establish at least a balance between the level of alteration of the Natural Environment and the benefits produced by this activity. Land Restoration and Environmental Impact Assessment Manual in Mining. InstitutoTecnológico GeoMinero de España, 1989. http://info.igme.es/SidPDF%5C065000%5C106%5C65106_0001.pdf	Unclear comment	CARLOS RAMIREZ SANCHEZ-MAROTO	AFA-ANDALUCIA	Spain

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
6023					My top-level concern with this chapter has to do with the discussions related to efficiency improvements. The problem with relying on efficiency improvements is that any gains will be swamped by rebound effects. This is true of both energy as well as material efficiency improvements. Part of this is because of the Jevons Paradox, stated in modern terms as the Khazzoom–Brookes postulate. Basically, any cost savings from efficiency improvements are typically reinvested to expand production (this effect is particularly evident in aggregate, rather than at firm level). But it is also because in a growth-oriented economy, efficiency gains are typically deployed specifically for the sake of more growth, in other words, in order to expand extraction and production, rather than to reduce it. Indeed, economists believe that efficiency improvements are good *because* they facilitate growth, and we know that growth is tightly coupled with energy and material throughput. It is not clear, then, why we would expect that efficiency improvements would on their own suddenly have the opposite effect. This is not a reasonable assumption. This problem is reviewed in this 2019 article: https://www.tandfonline.com/doi/abs/10.1080/13563467.2019.1598964. There is now a substantial empirical literature on rebound effects, which should be mentioned in this chapter (as of now the concept is absent from the text). The proposals in this chapter for improving material efficiency are robust, but they must be protected against rebound effects by using caps on material and energy throughput (or by raising taxes on resource extraction, although this is perhaps less effective). Capping will ensure that any improvements in efficiency result in aggregate reduction of energy and material use, rather than getting wiped out by rebound effects. There are a number of published scientific articles on capping fossil fuels and emissions (https://link.springer.com/article/10.1007/s10584-018-2162-x; https://www.tandfonline.com/doi/abs/10.1080/17583004.2015.1021563; https://www.tandfonline.com/doi/abs/10.1080/15487733.2008.11908010; http://www.teqs.net/Tyndall2005.pdf); this principle can be extended to energy and materials. Crucially, this should come along with policy on working-time reduction, so as to avoid any unemployment that might result from a reduction of throughput. This policy has its own intrinsic benefits in terms of reducing throughput. Indeed, a shorter working week has been found to be one of the single most impactful policies in terms of reducing energy demand. Researchers have found that if the United States were to reduce its working hours to the levels of Western Europe, its energy consumption would decline by 20%. https://journals.sagepub.com/doi/abs/10.2190/D842-1505-1K86-9882	Will mention the view about rebound effect though there is an issue of assumption.	Jason Hickel	Goldsmiths, University of London	United Kingdom (of Great Britain and Northern Ireland)
6099					(2018b) stress that currently about half of the steel or	Editorial, thank you	CARLOS RAMIREZ SANCHEZ-MAROTO	AFA-ANDALUCIA	Spain
6101					21 Aluminum is discarded or oversized for specific services. It is worth remembering that it is no longer necessary to extract virgin metal from a mine, now we have it much more available to us with "urban mining", which consists in collecting disused metal for recycling and reinstatement as a new raw material. It is called "urban" because scrap is mainly found in cities and industrial estates. Only the aluminium stock in the e-distribution networks is equivalent to 120% of the annual production of this metal in Spain. The only case where 100% of the metal comes from recycling is lead, according to data provided by the FER. For other major metals, 80% of the copper used by the industry is recycled and, in the case of aluminium and steel, the percentage is 75%. That is, more than three-quarters of the lead, copper, aluminum and steel used comes from recycling. Metal can be recycled indefinitely without losing its quality or properties. Recycling aluminum instead of opting for extraction saves 95% energy and prevents the emission of 3.54 tons of CO2 per tonne recycled. It is economically more economically more feasible to use recycled metals than to extract new resources, in many cases. In particular, recycling aluminum rather than opting for extraction is a 95% energy saving, according to data from the International Recycling Office. In copper, the savings are 85%; in iron and steel, 74%; and, in lead, 65%. (https://ethic.es/2019/01/innovacion-mineria-urbana/)	OK	CARLOS RAMIREZ SANCHEZ-MAROTO	AFA-ANDALUCIA	Spain
9421					fig 11.9 is not visible	Noted thank you this will be corrected for	ANNA LAURA PISELLO	DEPARTMENT OF ENGINEERING - UNIVERSITY OF PERUGIA, ITALY	Italy
18363					The regional balance of Lead Authors in this chapter must be considered. More from emerging economy and developing nations are necessary.	Beyond our power	Kazuhiko Hombu	Graduate School of Public Policy, The University of Tokyo	Japan
25533					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 stataments as policy prescriptive.	accept	Sarah Connors	IPCC WGI TSU	France
25567					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.	Accept	Sarah Connors	IPCC WGI TSU	France
29061					Repeated citation of IEA, Material Economics and Energy Transitions comission	Correct. Now revised	Priyadarshi Shukla	Ahmedabad University	India
33109					I trust that there are over productions for many sectors. Limit to production policy can be justified. For example, behaviour aspect of food and clothing wastage may have implication to climate change. Inddiviual celling or limit can be applied. It could be even voluntarily for some next ten years which help to generate individual awareness	Vague comment.	Edris Alam	Rabdan Acadmey	United Arab Emirates
36367					Although industry is affected by many types of policy options and others such as infrastructure and the people's behavior, the analysis of policy options and others have better places to be discussed in other chapters. The analysis and discussion here had better focus on the issues specific to industrial input and output, the direct (or significant) spillovers (or impact in the process of use, discard, recycle and so on), or specific influences by specific policy and other measures to avoid duplication and to deepen the analysis in this chapter.	Vague comment. Policy is necessary in this chapter.	Shigetaka Seki	Consumer Product Safery Association	Japan

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
38583					Repeated comment from previous review. Comment on the entire chapter: This chapter needs more information on energy efficiency since it has historically contributed the most to emissions reductions and is still considered on of the largest migitation potential options. In addition, most energy efficiency options are already commercialized and generally cost-effective. See Chang et al. 2019 (cited numerous times in Chapter 2) which demonstrates that energy efficiency improvements (reductions in energy intensity) are the main contributor to emissions reductions 2001-2014. To quote Chapter 2: "Chang et al. (2019) decompose and quantify the effects of different drivers from 2001 to 2014, that is, population, affluence, energy intensity and carbon intensity, across time on global carbon emissions and find that energy intensity effect (energy consumed per unit of income) is the leading contributor for carbon emission mitigation, whereas affluence (income per capita) and population serve as factors accelerating carbon emissions." This conclusion is consistent across geographic regions also - they find that energy intensity reduction contributed the most to emissions reductions in Africa, Latin America, India, China, and the E.U.	Understood points. Will see how to improve it.	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
38585					Repeated comment from previous review. Comment on the entire chapter: I recommend that you develop an organizing storyline for this chapter that could, for example, start with demand reduction (e.g. material efficiency), then to energy efficiency as the available near-term, commercial, low-cost option, then to electrification *if* the grid is decarbonized or *if* the electricity is non-fossil, then to longer-term options like CCS and some not-yet commercialized or cost-effective decarbonization technologies. In this way, you will provide the reader with a roadmap regarding what can be done in the near-term vs long-term and what needs further R&D for commercialization, scaling, and cost-reduction.	Thanks. Accepted	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
38587					Repeated comment from previous review. Comment on the entire chapter: This chapter is a bit EU-centric and very much needs more information on China, the world's largest producer of most of the industrial materials discussed. China's industrial sector accounts for ~70% of its primary energy use and energy-related CO2 emissions. There have been many 2050 potential studies for China in recent years that could be cited.	Agree.Revisions made accordingly but EU has a clear lead in industrial decarbonisation	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
38589					Repeated comment from previous review. Comment on the entire chapter: I note the following from the IPCC's 1.5 Degrees report: "Broadly speaking, the industry sector's mitigation measures can be categorized in terms of the following five strategies: (i) reducing demand, (ii) energy efficiency, (iii) increasing electrification of energy demand, (iv) reducing the carbon content of non-electric fuels, and (v) deploying innovative processes and application of CCS. IEA ETP estimates the relative contribution of different measures for CO2 emission reduction in their B2DS scenario compared with their reference scenario in 2050 as follows: energy efficiency 42%, innovative process and CCS 37%, switching to low-carbon fuels and feedstocks 13% and material efficiency (include efficient production and use to contribute to demand reduction) 8%."	Thanks. We try to emphasise what is new since previsou reports and highlight options for zero emissions. We do not intend to downplay the importance of EE	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
38591					Repeated comment from previous review. Comment on the entire chapter: I note the following from the IPCC's 1.5 Degrees report: "The combined evidence suggests that aggressive policies addressing energy efficiency are central in keeping 1.5°C within reach and lowering energy system and mitigation costs (high confidence) (Luderer et al., 2013; Rogelj et al., 2013b, 2015b; Grubler et al., 2018). Demand-side policies that increase energy efficiency or limit energy demand at a higher rate than historically observed are critical enabling factors for reducing mitigation costs in stringent mitigation pathways across the board (Luderer et al., 2013; Rogelj et al., 2013b, 2015b; Clarke et al., 2014; Bertram et al., 2015a; Bataille et al., 2016b)."	Understood points. Will see how to improve it.	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
38595					I note that the Material Economics 2019 study - which covers Europe only - is cited ~40 times in this chapter. The IPCC Assessment Reports are surveys of the recent literature. As such, this report is valuable to include, but it seems that it is too heavily relied upon and as a result many parts of the chapter seem skewed to focus on material efficiency and Europe. I suggest more references from other economies and a more balanced focus on all industry sector mitigation options.	Thanks. Revised	Lynn Price	Lawrence Berkeley National Laboratory	United States of America
38597					The IEA has a new report out on energy efficiency (Energy Efficiency 2019) which documents a slowing in primary energy intensity improvement globally. It would be very interesting to include some of the information from this report in your chapter. I note the following from the executive summary: "The slowdown in global energy efficiency improvement, despite the potential for costeffective savings, underscores the need for urgent policy action. New ways of policy thinking that move beyond traditional approaches are required, particularly to maximise the potential efficiency gains from digitalisation. The Global Commission for Urgent Action on Energy Efficiency brings together national leaders, ministers, top business executives and global thought leaders to consider how to accelerate global progress on energy efficiency. The Commission will publish its recommendations in mid-2020, which will be explored in next year's edition of this report."	Thanks. Will check it.	Lynn Price	Lawrence Berkeley National Laboratory	United States of America

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
39089					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). 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).	We agree with this comment and 11.3.6 will be revised accordingly. We do not, however, have space to include everything	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
39091					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).	We agree with this comment and 11.3.6 will be revised accordingly. We do not, however, have space to include everything	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
39093					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).	We agree with this comment and 11.3.6 will be revised accordingly. We do not, however, have space to include everything	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium

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39095					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	We agree with this comment and 11.3.6 will be revised accordingly. We do not, however, have space to include everything	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
39097					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. 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	rejected: In the hydrogen box in section 11.3 it is discussed that it is not only hydrogen that is required for achieving GHG mitigaton goals, but a broad range of to hydrogen-based fuels, including synthetic methane, synthetic liquid fuels, ammonia and methanol. The term power to fuels is not used here directly but hydrogen based fuels. In 11.4 at some parts hydrogen based products (e.g. green methanol in section 11.4.1) is also mentioned. Alos in 11.4.2 it is mentioned thta hydrogen is used a synonym for hydrogen + hydrogen based products.	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
39099					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). • 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.	Thanks. CCUS split to CCU and CCS, and relevant references added	Célia Sapart	Université Libre de Bruxelles et Co2 Value Europe	Belgium
42837					Chapter 10 "Freight transport industries are the major causes for increasing the CO2 emissions within the supply chain (Makan & Heyns, 2018)". Industry decisions on material sourcing, supply chain design, transport modes, location of production and distribution facilities, product design and packaging determin the demand for freight transport which contributes 41% to transport greenhouse gas emissions ITF, (2017). ITF Transport Outlook 2017. OECD Publishing, Paris. https://doi.org/10.1787/9789282108000-en. The role of Industry in generating and mitigating freight transport emissions needs to be much more clearly addressed in this Chapter.	Reject. For Transport chapter	Mark MAJOR	Partnership on Sustainable Low Carbon Transport	Spain
48061					Comment on ES : What is the link between material intensity and greenhouse gas emissions? What are the key drivers of the increase in material intensity?	Thanks. Now in 11.2	Valérie Masson-Delmotte	CEA, IPSL/LSCE	France
48063					Coordination with WGI (chapter 5, carbon cycle, land and ocean productivity in a warmer world) and also with the AFOLU chapter of WGIII is needed on the availability of biomass for multiple uses (energy, feedstock, carbon storage, food, fiber, feed, paper…) =>important for a systemic approach and for the coherency of the assessment	Good point. Dealt with through Biomass BOG and cross WG collaboration	Valérie Masson-Delmotte	CEA, IPSL/LSCE	France
48065					ES : thank you for being explicit on education needs. A clear message on the assessment of education aspects stemming from various perspectives , WG3 chapters and across WG is needed (climate change literacy, lifelong training, skills etc).	OK	Valérie Masson-Delmotte	CEA, IPSL/LSCE	France
48067					ES / chapter outline : I was looking at the chapter outline and ES for information on the relative weight of various sectors and could not find information on the fashion / clothing / fiber sector in terms of GHG emissions and mitigation potential. Not sure where this is covered.	Beyond our scope although synthetic fibre is mentioned. Fashion should be in Ch5?	Valérie Masson-Delmotte	CEA, IPSL/LSCE	France