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
15885	0	0			I would suggest for this chapter to include a paragraph covering the emerging role of agent based modelling (ABM) within integrated assessment modelling (IAM) frameworks. ABM models and simulates a number of agents who are players and especially investors, operating and decommissioning or refurbishing old assets and investing in new assets. Their investment decision making process is based on a number of criteria including capital and operating costs, return on investment, etc., and are strongly influenced by regional and international economic and policy environments. ABM can capture CO_2 lock-in effect when the lack of a viable business model pushes the agents/investors to invest in carbon intensive assets (which could be operating for 20 to 40 years) due to their higher profitability. References: 1- An agent-based modelling approach to simulate the investment decision of industrial enterprises Budinis, S., Sachs, J., Giarola, S., Hawkes, A. Journal of Cleaner Production, 2020, 267, 121835 2- Agent-based scenarios comparison for assessing fuel-switching investment in long-term energy transitions of the India's industry sector Moya, D., Budinis, S., Giarola, S., Hawkes, A. Applied Energy, 2020, 274, 115295	Reject, this chapter is not about modelling	Leila Rashidian	International Energy Agency	France
52561	0	0			Cost assesment should be provided and it should include cost of infrastructure and deployment.	Costs and potentials are provided for mitigation options. Infrastructure cost implications are very contextual. The scope of costs will be noted	Government of United States of America	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral	Saudi Arabia
52569	0	0			The report should highlight the implication of electrification on energy intnsive industries.	Thanks. It does this throught the chapter	Behzad Layeghi	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral	Saudi Arabia
52569	0	0			The report should highlight the implication of electrification on energy intnsive industries.	Yes agreed.	Behzad Layeghi	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral	Saudi Arabia
84085	0	0			May be useful to examine evidence on the limited number of carbon pricing-related schemes that have specifically targeted less energy-intensive and commercial businesses - which generally seem to have significant impacts IF they are designed in ways that address informational/behavioural as well as economic incentives. Most recent, a new book with analysis of how combinations of economic and behavioural incentives arising from the metropolitan ETS schemes in Tokyo and Saitama (which also covered manufacturing) led to substantial emission savings across multiple sectors: Arimura, T. H., and S. Matsumoto, 2021: Carbon Pricing in Japan. SpringerLink, Tokyo. Some other Asian schemes have some similarities, and they have some things in common with the UK 'CRC energy efficiency scheme' which had a major impact when introduced, - AR5 may have evaluated but I dont think so (Grubb, M; Haney, A; Wilde, J. (2009), Plugging the gap in energy efficiency policies: the emergence of the UK carbon reduction commitment. European Review of Energy Markets, Vol. 8)	This could be added to 11.6.1 on carbon prices	Philippe Waldteufel	UCL - Institute of Sustainable Resources	United Kingdom (of Great Britain and Northern Ireland)
84883	0				I estimate that this chapter could be reduced in length by at least 10% while improving clarity through some aggressive copyediting. There are numerous repetitive passages (e.g. on p16-17 repeated on p26), or the numerous descriptions of the LEILAC project.	Thanks. Final chapter length will fit the given page limit	Government of United States of America	ClimateWorks Foundation	United States of America
84883	0				I estimate that this chapter could be reduced in length by at least 10% while improving clarity through some aggressive copyediting. There are numerous repetitive passages (e.g. on p16-17 repeated on p26), or the numerous descriptions of the LEILAC project.	Yes, agreed, chapter will be edited	Government of United States of America	ClimateWorks Foundation	United States of America
84911	0				Most of the numbers in the chapter were cited as MtCO_2 or MtCO_2e, but some were cited as MtC (ep on p37). Please use one unit consistently.	Accepted	Government of United States of America	ClimateWorks Foundation	United States of America
23287	0				Talking about the Industry in Chapter 11 could also include industrial impacts on the ocean and the ocean industry linked with the blue economy. For instance, ocean dumping of industrial waste, industrial spills or pollution caused by industrial wastewater is a central topic for a lot of countries. (NOAA, 2021) (EPA, 2020) (Lawson, 2018) (MarineBio, Undated) (Wood et al. 1993)	Rejected. There are multiple ways industry impact envoironment, but this chapter is on mitigation not on impacts.	Rebecca Dell	Ministère de la Transition écologique et solidaire	France
28651	0		0		IEA ETP 2020 is referenced, I would also recommend IEA Special Report on CCUS (2020) to be read by those covering CCUS aspects, for the future roles for CCUS in reducing emissions from industry.	Thanks but we already cite WEO which has much information and the IEA report Transforming industry through CCUS	Government of United States of America	IEAGHG	United Kingdom (of Great Britain and Northern Ireland)
43941	0				Rick Bohan, Vice President, Sustainability at the Portland Cement Association (PCA) welcomes the opportunity to conduct this expert review of the UN IPCC Industry Chapter of the Sixth Assessment Report and submit comments. PCA, founded in 1916, is the premier policy, research, education, and market intelligence organization serving America's cement manufacturers. PCA members represent over 90 percent of US cement production capacity and have facilities in all 50 states. The Association promotes safety, sustainability, and innovation in all aspects of construction, fosters continuous improvement in cement manufacturing and distribution, and generally promotes economic growth and sound infrastructure investment. Cement and concrete product manufacturing, directly and indirectly, employs approximately 610,000 people in our country, and our collective industries contribute over $125 billion to our economy.	Thanks. Cement is given much attention in the chapter	Tim Dixon	Portland Cement Association	United States of America
43943	0				PCA and the cement industry signed an ambition statement for the U.S. cement and concrete industry to be carbon neutral across the concrete supply chain by 2050, in alignment with the goal to reach carbon neutrality by 2050. Cement is an integral component in concrete, the second most used building material globally after water. It is required for nearly all aspects of our built environment including buildings, pavements, bridges, dams, and other forms of infrastructure, providing a resilient, long-lasting, and sustainable foundation for the nation's economy. Considered across its full lifecycle, cement and concrete products significantly advance core federal decarbonization and climate adaptation goals by increasing the energy efficiency and climate-resilience of buildings, increasing the fuel efficiency of vehicles through more efficient pavement vehicle interaction (PVI), and reducing urban heat island effects by increasing the reflectivity, or albedo, of the built environment.	Thanks. Cement is given much attention in the chapter	Sara Budinis	Portland Cement Association	United States of America
43943	0				PCA and the cement industry signed an ambition statement for the U.S. cement and concrete industry to be carbon neutral across the concrete supply chain by 2050, in alignment with the goal to reach carbon neutrality by 2050. Cement is an integral component in concrete, the second most used building material globally after water. It is required for nearly all aspects of our built environment including buildings, pavements, bridges, dams, and other forms of infrastructure, providing a resilient, long-lasting, and sustainable foundation for the nation's economy. Considered across its full lifecycle, cement and concrete products significantly advance core federal decarbonization and climate adaptation goals by increasing the energy efficiency and climate-resilience of buildings, increasing the fuel efficiency of vehicles through more efficient pavement vehicle interaction (PVI), and reducing urban heat island effects by increasing the reflectivity, or albedo, of the built environment.	Thank you for this interesting information. The chapter length does not allow elaboration of these benefits.	Sara Budinis	Portland Cement Association	United States of America
43945	0				The cement industry agrees with the industry decarbonization levers that IPCC has indicated in the Industry Chapter: carbon capture, utilization, and sequestration (CCUS), fuel switching, energy efficiency, blended cements, and advanced technologies, including hydrogen fuels and kiln electrification.	Thanks. Cement is given much attention in the chapter	Government of Saudi Arabia	Portland Cement Association	United States of America
43945	0				The cement industry agrees with the industry decarbonization levers that IPCC has indicated in the Industry Chapter: carbon capture, utilization, and sequestration (CCUS), fuel switching, energy efficiency, blended cements, and advanced technologies, including hydrogen fuels and kiln electrification.	Thank you	Government of Saudi Arabia	Portland Cement Association	United States of America
43947	0				The costs to construct and operate emissions abatement technology are an ever-present concern for cement manufacturers and their downstream customers. As with other energy-intensive, trade-exposed (EITE) industries, cement manufacturers compete in a highly cost-constrained global market economy. Cement is a fungible global commodity, and domestic cement manufacturers have limited ability to pass the cost of significant new carbon abatement investments on to customers where lower-cost, often higher-carbon imported cement products are available. These market dynamics make economic and carbon leakage a very real concern and must be addressed in addition to implementing measures to decarbonize the cement industry. If the U.S. is to maintain a healthy domestic cement industry and the jobs and contributions to the domestic economy it provides, viable decarbonization tools and strategies must allow domestic manufacturers to remain competitive both at home and abroad.	Due to the weight of cement we don´t agree that it is such a fungible global commodity nevertheless the importance of a level playing field and competitiveness is a prominent issue in the chapter.	Government of Saudi Arabia	Portland Cement Association	United States of America
51269	0				Nuclear energy is a non-zero carbon emissions. It works with fluids (Liquid or gas) at high temperatures, then the heat is able to use in the industry, and in the hydrogen generation. For this reason in this chapter the nuclear energy, or well nuclear power plants should be considered as an alternative to others energies in the industry, for reducing emissions.	Thanks, but it is the subject for the chapter 6 - energy	Michael Grubb	Universidad Politécnica de Madrid (UPM)	Spain
51269	0				Nuclear energy is a non-zero carbon emissions. It works with fluids (Liquid or gas) at high temperatures, then the heat is able to use in the industry, and in the hydrogen generation. For this reason in this chapter the nuclear energy, or well nuclear power plants should be considered as an alternative to others energies in the industry, for reducing emissions.	Certainly nuclear energy is an option for industry to decarbonise but this is an issue for the energy chapter	Michael Grubb	Universidad Politécnica de Madrid (UPM)	Spain
84113	0				Great chapter. Pity I don't have time to comment - but not much need. I'd be interested to be reassured about consistency between the industry and transport chapters and the following: Comment from a colleague at UCL: "Have you / reviewers taken UNEP EGR as an input. Ch. 6? This has some content on TRL. There are already investments and orders in for ammonia powered ships and GW scale green ammonia supply chains targeted at marine. There are bio/e-methanol powered ships and 2nd gen/waste bio fuels already in operation (which I don't fancy as scalable but still important as a stop gap as we scale ammonia). Both supply chain and fleet are therefore on track for full TR maturity by 2025. Most of the info is in the grey literature (and often specialist/shipping grey lit), so hard to use/access. What has perhaps confused authors/reviewers is that there are lobbying vested interests for different fuels which can give the impression that there is lack of clarity on tech pathway. Lots of content that could be leveraged here: https://wedocs.unep.org/xmlui/bitstream/handle/20.500.11822/34431/EGR20ch5.pdf?sequence=3 " Also review Figure TS.22 in light of this?	Hydrogen and hydrogen carriers production and use for transport belongs mainly in the Energy and Transport chapter respectively. We deal extensively with industrial applications (including feedstock)	FABIO RUBENS SOARES	UCL - Institute of Sustainable Resources	United Kingdom (of Great Britain and Northern Ireland)
84903	0				The authors seem undecided about the use of the term "hard to abate". It appears in many places throughout the chapter (p34, 38, 37, and many other places). This is a value-laden and innacurate term (as you point out on p38), so it should be avoided in an assessment like this document. There are plenty of value-neutral alternatives, like "heavy industry" or "commodity industry" or "materials industry". I strongly suggest that you remove all occurrences of it.	Agree. Hard to abate should not be used except to tell that it is a misleading designation	Christian Breyer	ClimateWorks Foundation	United States of America
57023	1	1	13	23	Somewhere in this text, it may be useful to discuss why material intensity is going up. Yes, it is coupled with GDP growth. But why? Is it due to urbanization? Improved living standard? Human behaviors? Demanding too much?	accepted	Government of United States of America	U.S. Department of State	United States of America
78771	1	1	98	37	the wording 'CCUS' is highly misleading and shall be split to 'CCU' and 'CCS'. Both concepts are highly different, and it is increasingly found in research that they are applied in a strongly opposed manner: CCU corresponds with Power-to-X and low-cost renewable electricity, while CCS is linked to fossil fuel use and the implicit assumption/input of high-cost renewable electricity. More can be found in Breyer et al. (https://www.cell.com/joule/fulltext/S2542-4351(19)30413-1) and Bruhn et al. (https://www.sciencedirect.com/science/article/pii/S1462901116300508)	Accepted	Antoine BONDUELLE	LUT University	Finland
78771	1	1	98	37	the wording 'CCUS' is highly misleading and shall be split to 'CCU' and 'CCS'. Both concepts are highly different, and it is increasingly found in research that they are applied in a strongly opposed manner: CCU corresponds with Power-to-X and low-cost renewable electricity, while CCS is linked to fossil fuel use and the implicit assumption/input of high-cost renewable electricity. More can be found in Breyer et al. (https://www.cell.com/joule/fulltext/S2542-4351(19)30413-1) and Bruhn et al. (https://www.sciencedirect.com/science/article/pii/S1462901116300508)	Agree. We failed to wash out CCUS from SOD but it was our intention	Antoine BONDUELLE	LUT University	Finland
3987	1		132		The text is very clear, complete and objective. It brings, in my understanding, fundamentally all the information pertinent to the treated subject. The section is very well written and the authors were very responsible and assertive in dealing with the subject in question. For these reasons I have nothing significant to add as I understand that the topic is being treated very clearly and completely. The authors are to be congratulated for the excellent work.	Thank you	Yuan Yao	USP - Universidade de São Paulo	Brazil
79181	4	1	98	36	I am encouraged by the improvement in content and clarity since AR5, and wish to make two chapter-wide comments about important concepts in citations that the authors regrettably do not seem to have received or have overlooked. The first is about integrative design. As I commented on 3:15:20, an important 2018 paper at doi:10.1088/1748-9326/aad965 rethinks design—how technologies are chosen, combined, timed, and sequenced. Whole-system design of industrial processes and equipment, not only of vehicles and (where it's most understood) buildings, can make the whole energy-efficiency resource severalfold larger than conventionally assumed, yet cheaper, often with increasing returns. Other papers show that integrative design and indeed energy efficiency generally are largely neglected in IAMs (doi:10.1088/1748-9326/ab55ab), causing most to gravely understate the quantity and overstate the cost of end-use efficiency, but that energy efficiency may help to accelerate the already dramatic flight of financial capital from fossil fuels to renewables and efficiency (10.1088/1748-9326/abc3f2) because its transmissibility by memes, phrases, and images at potentially the speed of social media could greatly accelerate its spread, perhaps even rivaling that of solar scaleup—relevant to this chapter's discussion of impediments to wide adoption. the last of these citations illustrates the power of integrative design in industry by graphing >$50b worth of industrial redesigns, mainly for large corporate owners, in a wide range of old and new industries. Integrative design typically found savings of ~30-60% in retrofit with paybacks of a few years, and ~40–90+% in newbuilds with nearly always lower capital cost. Dis-integrated conventional design cannot and does not achieve such results, but remains the norm for most practitioners and analysts. Yet it's very big. As a small example, optimizing pipe and duct design has a global potential, if everyone did it, to save ~2/5 of the world's electricity, with paybacks <1 y in retrofit and <0 in newbuilds, yet it's not in any standard engineering text, government study, industry forecast, or climate model—because it's not a technology but a design method, and few people yet think of design as a scaling vector. I do urge the authors to peruse these three foundational papers and see what additions or revisions they think are best to reflect the existence of this practice and its relevance to the industrial sector.	Thank you. We made this point on IEA even in ES. We do reflect the importance of intergated designs. Reference is added	Government of United States of America	Rocky Mountain Institute; also Adjunct Professor of Environmental & Civil Engineering, Stanford University	United States of America

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
79183	4	1	98	36	My second generic comment is about the remarkably big yet still underscoped importance of materials efficiency. Restating my comments on Chapter 9, 1:0–92:29: The discussion of embodied energy touches briefly on circularity but omits a major category of opportunities. Most of the world's concrete (which uses half of cement directly, the rest in blocks, plasters, mortars, screeds,… mainly for buildings), as well as most of the world's structural steel, are wasted, on two different [and largely independent] lines of analysis. The first (doi:10.1038/s43017-020-0093-3) notes a >2x, generally ~3x, cement-saving potential by designing out excessive cement and wasted concrete (due to sloppy construction practices). The second is synthesized and documented in Lovins 2021, "Profitably decarbonizing heavy transport and indusrial heat," provided to WG3 leaders (but apparently it didn't reach you, alas) in draft in Nov 2020, in press for April 2021 release by RMI (www.rmi.org), summarized and strategically augmented by "Six business revolutions to decarbonize heavy transport and industrial heat," in press for June 2021 publication by MIT Sloan Management Review. This second opportunity space shows that proven innovations in structural design, used by the world's best civil/structural engineers but not yet by most designers, can at least double concrete and steel's structural efficiency at dramatically lower cost: e.g. 80–90% materials savings from tension structures, ≥50% from fabric-form beams and sheets, 70–76% from thin corrugated or vaulted/ribbed floorslabs, and most of the mass of bridges and pillars from 3D-printed dendritic forms. Past assessments such as Energy Transitions Commission's 2018 Mission Possible seem to overlook these structural-design opportunities, whose description in engineering literature is evocative but fragmented. Th[e Buildings] Chapter, and...the Industrial chapter, should note these major structural-design opportunities to avoid, at a profit, most of the ~15% of CO2 released from cement and steel manufacture and use (not counting additional savings up to ~25–30% from carbonation enabled by noncorroding concrete reinforcement, nor potential carbon-negative cements such as Solidia's carboxylate chemistries). (And by the way, each Hypercar, discussed in my Chapter 10 comments, displaces >1t of ferrous metals.) Please contact me (ablovins@stanford.edu) to tell me where to send you these two new papers. Though the technical one won't be in a peer-reviewed journal, at least initially, it's heavily documented from peer-reviewed journal sources, while MIT Sloan Management Review is one of the world's most respected journals at the interface of business and technology. As far as I know, these papers are the first decent synthesis of materials savings through radically efficient structural design. Meanwhile, hearty congratulations for concurring with and building on the Energy Transitions Commission's industrial decarb findings: my contribution is to show in convincing (and engagingly illustrated) detail that three years later, they were quite conservative in quantity and what they described as a modest cost is almost certainly a profit.	The industry chapter focuses mainly on material efficiency in the industrial facilities, leaving downstream design and end-user mateiral efficiency savings to the individual chapters of buildings and transport. Howeve, there is a short section 11.3.2 which covers ME across the entire lifecycle of materials and products, and the references provded have been added in the approproatie paragraphs.	Neeraj Ramchandran	Rocky Mountain Institute; also Adjunct Professor of Environmental & Civil Engineering, Stanford University	United States of America
79183	4	1	98	36	My second generic comment is about the remarkably big yet still underscoped importance of materials efficiency. Restating my comments on Chapter 9, 1:0–92:29: The discussion of embodied energy touches briefly on circularity but omits a major category of opportunities. Most of the world's concrete (which uses half of cement directly, the rest in blocks, plasters, mortars, screeds,… mainly for buildings), as well as most of the world's structural steel, are wasted, on two different [and largely independent] lines of analysis. The first (doi:10.1038/s43017-020-0093-3) notes a >2x, generally ~3x, cement-saving potential by designing out excessive cement and wasted concrete (due to sloppy construction practices). The second is synthesized and documented in Lovins 2021, "Profitably decarbonizing heavy transport and indusrial heat," provided to WG3 leaders (but apparently it didn't reach you, alas) in draft in Nov 2020, in press for April 2021 release by RMI (www.rmi.org), summarized and strategically augmented by "Six business revolutions to decarbonize heavy transport and industrial heat," in press for June 2021 publication by MIT Sloan Management Review. This second opportunity space shows that proven innovations in structural design, used by the world's best civil/structural engineers but not yet by most designers, can at least double concrete and steel's structural efficiency at dramatically lower cost: e.g. 80–90% materials savings from tension structures, ≥50% from fabric-form beams and sheets, 70–76% from thin corrugated or vaulted/ribbed floorslabs, and most of the mass of bridges and pillars from 3D-printed dendritic forms. Past assessments such as Energy Transitions Commission's 2018 Mission Possible seem to overlook these structural-design opportunities, whose description in engineering literature is evocative but fragmented. Th[e Buildings] Chapter, and...the Industrial chapter, should note these major structural-design opportunities to avoid, at a profit, most of the ~15% of CO2 released from cement and steel manufacture and use (not counting additional savings up to ~25–30% from carbonation enabled by noncorroding concrete reinforcement, nor potential carbon-negative cements such as Solidia's carboxylate chemistries). (And by the way, each Hypercar, discussed in my Chapter 10 comments, displaces >1t of ferrous metals.) Please contact me (ablovins@stanford.edu) to tell me where to send you these two new papers. Though the technical one won't be in a peer-reviewed journal, at least initially, it's heavily documented from peer-reviewed journal sources, while MIT Sloan Management Review is one of the world's most respected journals at the interface of business and technology. As far as I know, these papers are the first decent synthesis of materials savings through radically efficient structural design. Meanwhile, hearty congratulations for concurring with and building on the Energy Transitions Commission's industrial decarb findings: my contribution is to show in convincing (and engagingly illustrated) detail that three years later, they were quite conservative in quantity and what they described as a modest cost is almost certainly a profit.	Accepted. We consider ME as very important option	Neeraj Ramchandran	Rocky Mountain Institute; also Adjunct Professor of Environmental & Civil Engineering, Stanford University	United States of America
14827	4	6	4	13	Consistently with Chapter 3 TS4, this paragraph should also highlight the need for negative emissions (CDR - DACS/BECCS) to reach the net zero emissions target.	Rejected. CCS is mentioned and the extent to which CDR is needed is beyond the scope of Ch 11	PEDRO MORA PERIS	Indépendant consultant	France
14827	4	6	4	13	Consistently with Chapter 3 TS4, this paragraph should also highlight the need for negative emissions (CDR - DACS/BECCS) to reach the net zero emissions target.	Noted. What are the reasons for saying CDR instead of CCS	PEDRO MORA PERIS	Indépendant consultant	France
30561	4	6	4	13	If the description of "Net-zero emissions from the industrial sector is possible" is left, it would be better to delete the description of L8 "low carbon feedstocks" and L11 "gas." On the other hand, if negative emission technologies such as industrial process with BECCS and DACCS are described inside L6-13 on p.4, it is possible to leave the description of L8 "low carbon feedstocks" and L11 "gas."	Rejected. Unclear what would motivate this change. Chemical industry needs fossil free feedstock and CCS needs gas infrastructure	PEDRO MORA PERIS	Climate Change Division - Ministry of Foreign Affairs	Japan
30561	4	6	4	13	If the description of "Net-zero emissions from the industrial sector is possible" is left, it would be better to delete the description of L8 "low carbon feedstocks" and L11 "gas." On the other hand, if negative emission technologies such as industrial process with BECCS and DACCS are described inside L6-13 on p.4, it is possible to leave the description of L8 "low carbon feedstocks" and L11 "gas."	We disagree. DACCS and BECCS is included in CCS.	PEDRO MORA PERIS	Climate Change Division - Ministry of Foreign Affairs	Japan
47247	4	6	4	13	Written with a ' technology' and 'primary production' lens - as a result seems to cover only a narrow perspective. Misses the opportunity to assume a more broader systemic perspective, also underscoring the need to reorganize society and (smart) infrastructure to deliver on the required change in production systems and value retention (inputs, outputs and the flows /loops).	Rejected. This is the scopem of chapter 5	Eric Masanet	PBL Netherlands Environmental Assessme	Netherlands
47247	4	6	4	13	Written with a ' technology' and 'primary production' lens - as a result seems to cover only a narrow perspective. Misses the opportunity to assume a more broader systemic perspective, also underscoring the need to reorganize society and (smart) infrastructure to deliver on the required change in production systems and value retention (inputs, outputs and the flows /loops).	The chapter is written with care to not have a primary production lens and the statement does list demand, ME and CE	Eric Masanet	PBL Netherlands Environmental Assessme	Netherlands
60475	4	6	4	13	In this paragraph, CCU is considered as a complementary option to CCS while, in fact, CCU combines the actions cited in the first sentences of this paragraph. Indeed, CCU contributes to 1) energy and material efficiency in storing and transporting energy via the power-to x approach, to 2) the deployment of renewable energy in storing and transporting electricity.3) create renewable feedstock for the production of alternative fuels, chemicals and materials and it supports circular economy , This should be clearly stated because both CCU and CCS concept do not play at all the same role in such a context and such a sentence shows a misconception of what CCU is, does not relfect the litterature on the subject and might bring an inaccurate message to policy makers when it comes to develop a adequate policy context to allow for the deployment of CCU technologies (Bruhn et al., 2016, Arning et al, 2019, SAM, 2018,, SAPEA 2019, Hepburn et al., 2019), Also CO2-Based fuels/e-fuels should be cited as well as other alternative fuels next to hydrogen. References: e.g. •Styring et al., 2011, Carbon Capture and Utilization in the Green Economy. Centre for Low Carbon Futures, York.,•Ampelli et al., 2015, Phil.Trans.R.Soc.A, 373., •GCI, 2016: Global Roadmap Study of CO2U Technologies, LUX Research & Global CO2 Initiative., ,•Bushuyev et al., 2018, Joule, 2(5), pp.825-832. •SAPEA, 2018, Science Advice for Policy by EU Academies, Novel Carbon Capture and Utilisation Technologies-Research and Climate Aspects, Evidence Review Report, 2. •Hepburn et al., 2019, Nature, 575, 87-97. Breyer et al., 2019, •Kätelhön et al., 2019, PNAS, 116, 23, 11187-11194. •CCES, 2019: Carbon Utilization – A vital and effective pathway for decarbonization, Center for Climate and Energy Solutions.. •Arning et al. 2019, Energy Policy, 125, 235–249.•Bruhn et al., 2016, Environmental Science & Policy, 60, 38–43. •Cuéllar-Franca and Azapagic, 2015, J.CO2.Utili., 9, 82-102..SAM, 2018: Novel carbon capture and utilisation technologies, Scientific Advice Mechanism (SAM), Independent scientific advice for policy making.	Reject. While we agree in principle to the possibilities/contributions of CCU (and could add the limitations as well) it is not possible to elaborate on each option here	Eric Masanet	Université Libre de Bruxelles / CO2 Value Europe	Belgium
60475	4	6	4	13	In this paragraph, CCU is considered as a complementary option to CCS while, in fact, CCU combines the actions cited in the first sentences of this paragraph. Indeed, CCU contributes to 1) energy and material efficiency in storing and transporting energy via the power-to x approach, to 2) the deployment of renewable energy in storing and transporting electricity.3) create renewable feedstock for the production of alternative fuels, chemicals and materials and it supports circular economy , This should be clearly stated because both CCU and CCS concept do not play at all the same role in such a context and such a sentence shows a misconception of what CCU is, does not relfect the litterature on the subject and might bring an inaccurate message to policy makers when it comes to develop a adequate policy context to allow for the deployment of CCU technologies (Bruhn et al., 2016, Arning et al, 2019, SAM, 2018,, SAPEA 2019, Hepburn et al., 2019), Also CO2-Based fuels/e-fuels should be cited as well as other alternative fuels next to hydrogen. References: e.g. •Styring et al., 2011, Carbon Capture and Utilization in the Green Economy. Centre for Low Carbon Futures, York.,•Ampelli et al., 2015, Phil.Trans.R.Soc.A, 373., •GCI, 2016: Global Roadmap Study of CO2U Technologies, LUX Research & Global CO2 Initiative., ,•Bushuyev et al., 2018, Joule, 2(5), pp.825-832. •SAPEA, 2018, Science Advice for Policy by EU Academies, Novel Carbon Capture and Utilisation Technologies-Research and Climate Aspects, Evidence Review Report, 2. •Hepburn et al., 2019, Nature, 575, 87-97. Breyer et al., 2019, •Kätelhön et al., 2019, PNAS, 116, 23, 11187-11194. •CCES, 2019: Carbon Utilization – A vital and effective pathway for decarbonization, Center for Climate and Energy Solutions.. •Arning et al. 2019, Energy Policy, 125, 235–249.•Bruhn et al., 2016, Environmental Science & Policy, 60, 38–43. •Cuéllar-Franca and Azapagic, 2015, J.CO2.Utili., 9, 82-102..SAM, 2018: Novel carbon capture and utilisation technologies, Scientific Advice Mechanism (SAM), Independent scientific advice for policy making.	While we agree in principle the ES does not allow the elaboration of such detail. All the options listed are complementary	Eric Masanet	Université Libre de Bruxelles / CO2 Value Europe	Belgium
76335	4	6	4	13	In this paragraph, CCU is considered as a complementary option to CCS while, in fact, CCU combines the actions cited in the first sentences of this paragraph. Indeed, CCU contributes to 1) energy and material efficiency in storing and transporting energy via the power-to x approach, to 2) the deployment of renewable energy in storing and transporting electricity.3) create renewable feedstock for the production of alternative fuels, chemicals and materials and it supports circular economy , This should be clearly stated because both CCU and CCS concept do not play at all the same role in such a context and such a sentence shows a misconception of what CCU is, does not relfect the litterature on the subject and might bring an inaccurate message to policy makers when it comes to develop a adequate policy context to allow for the deployment of CCU technologies (Bruhn et al., 2016, Arning et al, 2019, SAM, 2018,, SAPEA 2019, Hepburn et al., 2019), Also CO2-Based fuels/e-fuels should be cited as well as other alternative fuels next to hydrogen. References: e.g. •Styring et al., 2011, Carbon Capture and Utilization in the Green Economy. Centre for Low Carbon Futures, York.,•Ampelli et al., 2015, Phil.Trans.R.Soc.A, 373., •GCI, 2016: Global Roadmap Study of CO2U Technologies, LUX Research & Global CO2 Initiative., ,•Bushuyev et al., 2018, Joule, 2(5), pp.825-832. •SAPEA, 2018, Science Advice for Policy by EU Academies, Novel Carbon Capture and Utilisation Technologies-Research and Climate Aspects, Evidence Review Report, 2. •Hepburn et al., 2019, Nature, 575, 87-97. Breyer et al., 2019, •Kätelhön et al., 2019, PNAS, 116, 23, 11187-11194. •CCES, 2019: Carbon Utilization – A vital and effective pathway for decarbonization, Center for Climate and Energy Solutions.. •Arning et al. 2019, Energy Policy, 125, 235–249.•Bruhn et al., 2016, Environmental Science & Policy, 60, 38–43. •Cuéllar-Franca and Azapagic, 2015, J.CO2.Utili., 9, 82-102..SAM, 2018: Novel carbon capture and utilisation technologies, Scientific Advice Mechanism (SAM), Independent scientific advice for policy making.	Reject, see previous comment	Government of United States of America	Flemish Institute for Technological Research (VITO)	Belgium
76335	4	6	4	13	In this paragraph, CCU is considered as a complementary option to CCS while, in fact, CCU combines the actions cited in the first sentences of this paragraph. Indeed, CCU contributes to 1) energy and material efficiency in storing and transporting energy via the power-to x approach, to 2) the deployment of renewable energy in storing and transporting electricity.3) create renewable feedstock for the production of alternative fuels, chemicals and materials and it supports circular economy , This should be clearly stated because both CCU and CCS concept do not play at all the same role in such a context and such a sentence shows a misconception of what CCU is, does not relfect the litterature on the subject and might bring an inaccurate message to policy makers when it comes to develop a adequate policy context to allow for the deployment of CCU technologies (Bruhn et al., 2016, Arning et al, 2019, SAM, 2018,, SAPEA 2019, Hepburn et al., 2019), Also CO2-Based fuels/e-fuels should be cited as well as other alternative fuels next to hydrogen. References: e.g. •Styring et al., 2011, Carbon Capture and Utilization in the Green Economy. Centre for Low Carbon Futures, York.,•Ampelli et al., 2015, Phil.Trans.R.Soc.A, 373., •GCI, 2016: Global Roadmap Study of CO2U Technologies, LUX Research & Global CO2 Initiative., ,•Bushuyev et al., 2018, Joule, 2(5), pp.825-832. •SAPEA, 2018, Science Advice for Policy by EU Academies, Novel Carbon Capture and Utilisation Technologies-Research and Climate Aspects, Evidence Review Report, 2. •Hepburn et al., 2019, Nature, 575, 87-97. Breyer et al., 2019, •Kätelhön et al., 2019, PNAS, 116, 23, 11187-11194. •CCES, 2019: Carbon Utilization – A vital and effective pathway for decarbonization, Center for Climate and Energy Solutions.. •Arning et al. 2019, Energy Policy, 125, 235–249.•Bruhn et al., 2016, Environmental Science & Policy, 60, 38–43. •Cuéllar-Franca and Azapagic, 2015, J.CO2.Utili., 9, 82-102..SAM, 2018: Novel carbon capture and utilisation technologies, Scientific Advice Mechanism (SAM), Independent scientific advice for policy making.	See above. Same comment	Government of United States of America	Flemish Institute for Technological Research (VITO)	Belgium
77139	4	6	4	13	The report asserts that "net-zero" is possible, but fails to acknowledge that such an ambition is unaffordable.	Rejected. The ES says - The technological capacity for very low to zero emissions industrial materials exists. Costs will be high for primary producers but low for final consumers and the general economy. This is stated in a later bullet point	Government of Germany	Expert Reviewer AR6 SOD WG1	Ireland
77139	4	6	4	13	The report asserts that "net-zero" is possible, but fails to acknowledge that such an ambition is unaffordable.	There is no evidence in the literature that this is unaffordable	Government of Germany	Expert Reviewer AR6 SOD WG1	Ireland

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
83719	4	6	4	13	In this paragraph, CCU is considered as a complementary option to CCS while, in fact, CCU combines the actions cited in the first sentences of this paragraph. Indeed, CCU contributes to 1) energy and material efficiency in storing and transporting energy via the power-to x approach, to 2) the deployment of renewable energy in storing and transporting electricity.3) create renewable feedstock for the production of alternative fuels, chemicals and materials and it supports circular economy , This should be clearly stated because both CCU and CCS concept do not play at all the same role in such a context and such a sentence shows a misconception of what CCU is, does not reflect the litterature on the subject and might bring an inaccurate message to policy makers when it comes to develop a adequate policy context to allow for the deployment of CCU technologies (Bruhn et al., 2016, Arning et al, 2019, SAM, 2018,, SAPEA 2019, Hepburn et al., 2019), Also CO2-Based fuels/e-fuels should be cited as well as other alternative fuels next to hydrogen. References: e.g. •Styring et al., 2011, Carbon Capture and Utilization in the Green Economy. Centre for Low Carbon Futures, York.,•Ampelli et al., 2015, Phil.Trans.R.Soc.A, 373., •GCI, 2016: Global Roadmap Study of CO2U Technologies, LUX Research & Global CO2 Initiative., ,•Bushuyev et al., 2018, Joule, 2(5), pp.825-832. •SAPEA, 2018, Science Advice for Policy by EU Academies, Novel Carbon Capture and Utilisation Technologies-Research and Climate Aspects, Evidence Review Report, 2. •Hepburn et al., 2019, Nature, 575, 87-97. Breyer et al., 2019, •Kätelhön et al., 2019, PNAS, 116, 23, 11187-11194. •CCES, 2019: Carbon Utilization – A vital and effective pathway for decarbonization, Center for Climate and Energy Solutions.. •Arning et al. 2019, Energy Policy, 125, 235–249.•Bruhn et al., 2016, Environmental Science & Policy, 60, 38–43. •Cuéllar-Franca and Azapagic, 2015, J.CO2.Utili., 9, 82-102..SAM, 2018: Novel carbon capture and utilisation technologies, Scientific Advice Mechanism (SAM), Independent scientific advice for policy making.	Rejected. Comment is identical to 2 other comments above	Government of Canada	LUT University	Finland
83719	4	6	4	13	In this paragraph, CCU is considered as a complementary option to CCS while, in fact, CCU combines the actions cited in the first sentences of this paragraph. Indeed, CCU contributes to 1) energy and material efficiency in storing and transporting energy via the power-to x approach, to 2) the deployment of renewable energy in storing and transporting electricity.3) create renewable feedstock for the production of alternative fuels, chemicals and materials and it supports circular economy , This should be clearly stated because both CCU and CCS concept do not play at all the same role in such a context and such a sentence shows a misconception of what CCU is, does not reflect the litterature on the subject and might bring an inaccurate message to policy makers when it comes to develop a adequate policy context to allow for the deployment of CCU technologies (Bruhn et al., 2016, Arning et al, 2019, SAM, 2018,, SAPEA 2019, Hepburn et al., 2019), Also CO2-Based fuels/e-fuels should be cited as well as other alternative fuels next to hydrogen. References: e.g. •Styring et al., 2011, Carbon Capture and Utilization in the Green Economy. Centre for Low Carbon Futures, York.,•Ampelli et al., 2015, Phil.Trans.R.Soc.A, 373., •GCI, 2016: Global Roadmap Study of CO2U Technologies, LUX Research & Global CO2 Initiative., ,•Bushuyev et al., 2018, Joule, 2(5), pp.825-832. •SAPEA, 2018, Science Advice for Policy by EU Academies, Novel Carbon Capture and Utilisation Technologies-Research and Climate Aspects, Evidence Review Report, 2. •Hepburn et al., 2019, Nature, 575, 87-97. Breyer et al., 2019, •Kätelhön et al., 2019, PNAS, 116, 23, 11187-11194. •CCES, 2019: Carbon Utilization – A vital and effective pathway for decarbonization, Center for Climate and Energy Solutions.. •Arning et al. 2019, Energy Policy, 125, 235–249.•Bruhn et al., 2016, Environmental Science & Policy, 60, 38–43. •Cuéllar-Franca and Azapagic, 2015, J.CO2.Utili., 9, 82-102..SAM, 2018: Novel carbon capture and utilisation technologies, Scientific Advice Mechanism (SAM), Independent scientific advice for policy making.	See reponse to comment 25-26	Government of Canada	LUT University	Finland
23269	4	7	4	7	Suggestion to replace "greenhouse gas (GHG) emissions free electricity and high temperature heat," with "GHG free energy carriers, such as electricity, high temperature heat and hydrogen" to emphasize the role of hydrogen which is mentionned afterwards alongside electrification	Yes, this has ben revised	Government of United States of America	Ministère de la Transition écologique et solidaire	France
23271	4	10	4	10	Concerning CCS : The chapter is more nuanced about CCU (p36 line 3-22). It does not say that it is a requirement for reaching net zero in the industrial sector. It is however possible to achieve net zero with CCU, provided that the reused carbon does not return to the atmosphere if it came from fossil fuels in the first place. Suggestion to rephrase : "electrification, hydrogen use, CCS, and, in some cases, CCU".	Proposed text doesn't change the high level ES statement. The role of CCS and CCU is elaborated in the chapter. CCU could indeed be a requirement, e.g., getting biogenic carbon into organic chemicals. "In some cases" can be applied to many options, depending on sector and where in the value chain	Government of United States of America	Ministère de la Transition écologique et solidaire	France
70401	4	10	4	12	The sentence calls for scaling up of gas infrastructure, while rightly there has been made no such plea in this chapter, as gas can only be used in specific circumstances in a low carbon economy	Accepted	Neeraj Ramchandran	European Union (EU) - DG Research & Innovation	Belgium
70401	4	10	4	12	The sentence calls for scaling up of gas infrastructure, while rightly there has been made no such plea in this chapter, as gas can only be used in specific circumstances in a low carbon economy	Hydrogen implies gas infrastructure. "gas" deleted	Neeraj Ramchandran	European Union (EU) - DG Research & Innovation	Belgium
85045	4	10	4	11	Reference to "[net zero from industry] requires substantial scaling up of […] gas […] infrastructure" may be a focus for debate and perhaps misinterpretation. Is this a reference to a role for fossil gas infrastructure in an industrial transition from coal-based heat; or to the use of gas infrastructure for blending or complete substitution of biogas and/or hydrogen?	Accepted. Mentioned options do not require expantion of gas infrastructure	Government of United States of America	Australian Industry Group	Australia
85045	4	10	4	11	Reference to "[net zero from industry] requires substantial scaling up of […] gas […] infrastructure" may be a focus for debate and perhaps misinterpretation. Is this a reference to a role for fossil gas infrastructure in an industrial transition from coal-based heat; or to the use of gas infrastructure for blending or complete substitution of biogas and/or hydrogen?	See comment 31 above	Government of United States of America	Australian Industry Group	Australia
85047	4	11	4	12	Reference to the need to phase out blast furnaces in steelmaking - is this a judgment that the CCS pathway for future steelmaking is not viable? That would be inconsistent with the text at page 11-5 lines 37-44, which considers steel pathways including CCS.	Thanks this has been revised	Government of Saudi Arabia	Australian Industry Group	Australia
10797	4	14	4	19	Perhaps it is not of fundamental interest to know which sector comes first ou second. On the other hand, it seems important to have a description in which significant emission sources are neither missing nor counted several times.	Thank you	Neeraj Ramchandran	CNRS	France
10797	4	14	4	19	Perhaps it is not of fundamental interest to know which sector comes first ou second. On the other hand, it seems important to have a description in which significant emission sources are neither missing nor counted several times.	The paragraph is intended to highlight the large and growing role of industry. Reject	Neeraj Ramchandran	CNRS	France
45587	4	14	4	15	Probably more interesting to report on the development since 2010 (which is quite different from the development 2000 -2010, see Figure on page 18.	Will be considered	Neeraj Ramchandran	Delft University of Technology	Netherlands
45587	4	14	4	15	Probably more interesting to report on the development since 2010 (which is quite different from the development 2000 -2010, see Figure on page 18.	Indeed growth has bee slower since 2010 but the statement is still valid.	Neeraj Ramchandran	Delft University of Technology	Netherlands
57025	4	14			The numbers in the Executive Summary for the overall amount of emissions attributed to the industrial sector do not match those in the text of the chapter (31% vs. 33%; see page 17, line 19). Also, how are F-gases treated with respect to inclusion in the industrial sector. This might be in Chapter 2, but even so it's worth restating somewhere in this chapter and perhaps in Figure 11.4 on page 21.	Will be finally checked for coinsistency after all data revisions are finished	Richard Bohan	U.S. Department of State	United States of America
57025	4	14			The numbers in the Executive Summary for the overall amount of emissions attributed to the industrial sector do not match those in the text of the chapter (31% vs. 33%; see page 17, line 19). Also, how are F-gases treated with respect to inclusion in the industrial sector. This might be in Chapter 2, but even so it's worth restating somewhere in this chapter and perhaps in Figure 11.4 on page 21.	This will be revised once we have the final data	Richard Bohan	U.S. Department of State	United States of America
57027	4	18	4	19	Suggested revision: "… emissions in 2018, second behind the energy transformation sector. Industry is the leading GHG emitter -- 19.3 GtCO2-eq or 31% in 2018 -- if indirect emissions from power and heat generation are included."	Accepted	Neeraj Ramchandran	U.S. Department of State	United States of America
57027	4	18	4	19	Suggested revision: "… emissions in 2018, second behind the energy transformation sector. Industry is the leading GHG emitter -- 19.3 GtCO2-eq or 31% in 2018 -- if indirect emissions from power and heat generation are included."	Good point	Neeraj Ramchandran	U.S. Department of State	United States of America
70403	4	19	4	19	Please notice that both in the SPM and Chapter 11.2.2 the relative figure of 33% is given, not 31%. Please harmonize numbers/messages	Will be finally checked for coinsistency after all data revisions are finished	Neeraj Ramchandran	European Union (EU) - DG Research & Innovation	Belgium
70403	4	19	4	19	Please notice that both in the SPM and Chapter 11.2.2 the relative figure of 33% is given, not 31%. Please harmonize numbers/messages	This will be checked and revised once we have final data set.	Neeraj Ramchandran	European Union (EU) - DG Research & Innovation	Belgium
57029	4	20			Didn't see evidence supporting the claim that the industrial sector has "high sensitivity to carbon price driven increases in production costs."	Reject, we specify that this concerns globally traded commodities. Discussed later in the chapter and originated from low profit margins and high competitiveness	Neeraj Ramchandran	U.S. Department of State	United States of America
57029	4	20			Didn't see evidence supporting the claim that the industrial sector has "high sensitivity to carbon price driven increases in production costs."	Emissions and energy intensive industries are sensitive since energy/emissions is high share of production cost. Have deleted "high" since it is disputed just how sensitive they really are (and it varies across subsectors).	Neeraj Ramchandran	U.S. Department of State	United States of America
57031	4	21	4	25	Authors should consider including that price of fuels and electricity will also impact the speed of the transition to a net-zero industrial sector. Low-cost natural gas, in the U.S. for example, disincentivizes electrification given higher costs for electricity.	It assumed that carbon price will make fossil fuels more expensive. Emissions free enegry now mentioned	Mark Preston Aragones	U.S. Department of State	United States of America
82683	4	22	4	22	lock-in OF long-lived capital stock	Thanks	Neeraj Ramchandran	Northwestern University	United States of America
70405	4	24	4	25	The argument about the high sensititivey to carbon pricing is complex to understand and without further clarification simply not true. High sensitivity to carbon pricing is in itself a good thing so industry may green sooner. However, what is probably being meant here is that it is difficult to put a carbon price for sectors that are internationally trading due to carbon leakage. Please specify more clear what is being meant here.	Rejected. Text is quite clear on the meaning - high sensitivity to carbon price driven increases in production costs for globally traded commodities.	Neeraj Ramchandran	European Union (EU) - DG Research & Innovation	Belgium
70405	4	24	4	25	The argument about the high sensititivey to carbon pricing is complex to understand and without further clarification simply not true. High sensitivity to carbon pricing is in itself a good thing so industry may green sooner. However, what is probably being meant here is that it is difficult to put a carbon price for sectors that are internationally trading due to carbon leakage. Please specify more clear what is being meant here.	This should already be clear from the reference to globally traded commodities	Neeraj Ramchandran	European Union (EU) - DG Research & Innovation	Belgium
57033	4	26	4	27	What's the unit? Tons?	Yes, it is clear from the chapter text. Tons added	Antoine BONDUELLE	U.S. Department of State	United States of America
57033	4	26	4	27	What's the unit? Tons?	Yes, thanks	Antoine BONDUELLE	U.S. Department of State	United States of America
82685	4	26	4	27	This statement needs more context. It appears to imply that greater materials per GDP is a bad thing, since it is contrasted against a clearly good trend (decreasing energy per GDP), but this materials intensity trend has also been fueling development. Can you make the key takeaway message clearer here? Is there some target/goal for materials/GDP that is ideal?	Rejected. Energy is also key for development, but its efficiency improves in contrast to materilas. This is a value neutral statement of facts	Government of United States of America	Northwestern University	United States of America
82685	4	26	4	27	This statement needs more context. It appears to imply that greater materials per GDP is a bad thing, since it is contrasted against a clearly good trend (decreasing energy per GDP), but this materials intensity trend has also been fueling development. Can you make the key takeaway message clearer here? Is there some target/goal for materials/GDP that is ideal?	This is just a factual statement and the ins and outs are explained in the chapter	Government of United States of America	Northwestern University	United States of America
57035	4	29	4	30	Authors probably don't need the 1971-2000 AAGR value (3.8%), just the 2000-2017 value (3.5%), to make this point.	Accepted	Mariel Vilella	U.S. Department of State	United States of America
57035	4	29	4	30	Authors probably don't need the 1971-2000 AAGR value (3.8%), just the 2000-2017 value (3.5%), to make this point.	We think it is relevant to show that it is a long term trend	Mariel Vilella	U.S. Department of State	United States of America
11479	4	30	4	30	The period "2000–2017" is different from what is presented in the main text (P.13, line 18). Please check and revise as appropriate.	Accepted	Government of United States of America	Hong Kong Observatory	China
11479	4	30	4	30	The period "2000–2017" is different from what is presented in the main text (P.13, line 18). Please check and revise as appropriate.	Yes, all numbers will be checked when we have the final data set.	Government of United States of America	Hong Kong Observatory	China
57037	4	33	4	34	Authors should add that fuel related emissions is due in part to successful efforts at improving energy efficiency.	Accepted	Eric Masanet	U.S. Department of State	United States of America
57037	4	33	4	34	Authors should add that fuel related emissions is due in part to successful efforts at improving energy efficiency.	Good point. Added	Eric Masanet	U.S. Department of State	United States of America
57039	4	34	4	35	"electrification and indirect emissions" is used in line 34. Does this include emissions from electricity (and heat)?	Yes, but we cannot list all alternatives and details.	Mariel Vilella	U.S. Department of State	United States of America
57039	4	34	4	35	"electrification and indirect emissions" is used in line 34. Does this include emissions from electricity (and heat)?	Thanks. Clarified	Mariel Vilella	U.S. Department of State	United States of America
10799	4	37	4	42	Actually Box 11.2 does not list any future possibilities, but section 11.3.6 gives some preliminary clues. However large R&D efforts and major investments will be necessary.	Accepted. Reference to 11.4.1.3 is given	Government of United States of America	CNRS	France
10799	4	37	4	42	Actually Box 11.2 does not list any future possibilities, but section 11.3.6 gives some preliminary clues. However large R&D efforts and major investments will be necessary.	Proper reference will be provided	Government of United States of America	CNRS	France
30563	4	43	4	45	L43-45 on p.4 "Scenario analyses show that significant cuts in GHG emissions and even close to net zero emissions from energy intensive industry ... can be achieved by 2050 ..." contradicts L6 on p.4 "Net-zero emissions from the industrial sector is possible." If the description of "Net-zero emissions from the industrial sector is possible" is left, it would be better to delete L43 on p.4 "close to."	No contradiction. The first statement shows no timeline for net zero, while the second one - does, and clearly refers to scenario analyses	Government of United States of America	Climate Change Division - Ministry of Foreign Affairs	Japan
30563	4	43	4	45	L43-45 on p.4 "Scenario analyses show that significant cuts in GHG emissions and even close to net zero emissions from energy intensive industry ... can be achieved by 2050 ..." contradicts L6 on p.4 "Net-zero emissions from the industrial sector is possible." If the description of "Net-zero emissions from the industrial sector is possible" is left, it would be better to delete L43 on p.4 "close to."	Thanks for spotting this. Should be distinguished as (IA) modelling scenarios	Government of United States of America	Climate Change Division - Ministry of Foreign Affairs	Japan

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
43949	4	43	4	45	I agree with this statement that the cement industry can achieve net-zero emissions by 2050 and aligns with the industry's goal to become carbon neutral across the concrete value chain by 2050.	Thanks	Government of United States of America	Portland Cement Association	United States of America
57041	4	43	5	4	The bold statement here says that significant cuts in GHG emissions even close to net zero can be made by 2050 by multiple and available options. Is this true? Don't authors show in Table 11.4 that industry also needs options that are currently at low TRLs, which aren't currently commercially available, and that are currently expensive? This statement should better reflect the full situation as reflected in the rest of the chapter.	Accepted	Eric Masanet	U.S. Department of State	United States of America
57041	4	43	5	4	The bold statement here says that significant cuts in GHG emissions even close to net zero can be made by 2050 by multiple and available options. Is this true? Don't authors show in Table 11.4 that industry also needs options that are currently at low TRLs, which aren't currently commercially available, and that are currently expensive? This statement should better reflect the full situation as reflected in the rest of the chapter.	Add emerging or under development?	Eric Masanet	U.S. Department of State	United States of America
47251	4	43	5	4	Requires further specification. ' Scenario analyses' is rather generic term. Simultaneously, section could use indication of geographical scale that is assumed here, or whether the ' scenario analyses' can be generalized to a global perspective.	Accepted	Cédric PHILIBERT	PBL Netherlands Environmental Assessme	Netherlands
47251	4	43	5	4	Requires further specification. ' Scenario analyses' is rather generic term. Simultaneously, section could use indication of geographical scale that is assumed here, or whether the ' scenario analyses' can be generalized to a global perspective.	Specify "sceanrio analyses"	Cédric PHILIBERT	PBL Netherlands Environmental Assessme	Netherlands
57043	4	44			Should aluminum be included in this list of industries?	Rejected. The list may be long, but literature mostly speaks on listed materials	Miguel Angel Sanjuán	U.S. Department of State	United States of America
57043	4	44			Should aluminum be included in this list of industries?	Yes, perhaps add aluminium	Miguel Angel Sanjuán	U.S. Department of State	United States of America
57045	4	45	5	1	Suggested re-wording: "It requires continued improvements that reduce energy demand (e.g., energy efficiency) coupled with transformational changes ..."	Rejected. The message is different. It is on *changing focus to* transformational change	Miguel Angel Sanjuán	U.S. Department of State	United States of America
57047	4	45	5	2	Energy efficiency will always be one of the key strategies because it preserves resources until other opportunities such as renewable energy are ready at scale. For example, to go renewable energy now without minimizing the energy needed through efficiency would result in wasted renewable energy as deployed inefficiently. Transformational strategies must go along with energy efficiency.	Accepted. "Mainly" added to indicate that EE does not become irrelevant	Aniceto Zaragoza	U.S. Department of State	United States of America
57047	4	45	5	2	Energy efficiency will always be one of the key strategies because it preserves resources until other opportunities such as renewable energy are ready at scale. For example, to go renewable energy now without minimizing the energy needed through efficiency would result in wasted renewable energy as deployed inefficiently. Transformational strategies must go along with energy efficiency.	Agree	Aniceto Zaragoza	U.S. Department of State	United States of America
57049	4	46	4	46	The denigration of energy efficiency as a pathway ignores the potential significant reductions that it can make in the near-term and the role that it can play in accelerated implementation of transformative technologies, such as electrification in reducing the demand for capital and resource intensive investments in new process assets. The text on page 11-8 uses the "supplementing" frame. It may also be appropriate to revisit the definition of energy efficiency since contemporary applications are more about time- and location-based reductions in energy demand that allow for better integration of variable resources (e.g., renewables) into the grid reducing the competition for storage technologies such as batteries to firm the grid.	Accepted. No intention to denigrate	Aniceto Zaragoza	U.S. Department of State	United States of America
57049	4	46	4	46	The denigration of energy efficiency as a pathway ignores the potential significant reductions that it can make in the near-term and the role that it can play in accelerated implementation of transformative technologies, such as electrification in reducing the demand for capital and resource intensive investments in new process assets. The text on page 11-8 uses the "supplementing" frame. It may also be appropriate to revisit the definition of energy efficiency since contemporary applications are more about time- and location-based reductions in energy demand that allow for better integration of variable resources (e.g., renewables) into the grid reducing the competition for storage technologies such as batteries to firm the grid.	Agree, will amend	Aniceto Zaragoza	U.S. Department of State	United States of America
47249	5	5	5	11	Seems better placed in chapter 3. Writing on page 25 (L42-47) on this subject seems more sharp.	Rejected. We discuss this issue in the chapter and it is worth making this statement. The IEAs provides different estimates versus sectorial models	Richard Bohan	PBL Netherlands Environmental Assessment Agency	Netherlands
47249	5	5	5	11	Seems better placed in chapter 3. Writing on page 25 (L42-47) on this subject seems more sharp.	Industry specific aspects shuold be kept here but aligned with p 25	Richard Bohan	PBL Netherlands Environmental Assessment Agency	Netherlands
57051	5	5	5	5	Add energy efficiency to the list: "Key climate mitigation options such as energy efficiency, materials efficiency, circular materials flows ..."	Accepted (if it is true!)	Alex Rau	U.S. Department of State	United States of America
57051	5	5	5	5	Add energy efficiency to the list: "Key climate mitigation options such as energy efficiency, materials efficiency, circular materials flows ..."	Reject since EE is in modeling	Alex Rau	U.S. Department of State	United States of America
74897	5	5	5	11	The under representation of key climate mitigation options in climate scenario modelling and intergrated modelling tools could also be atributed to data availability in the form that allows it to be integrated into major emmision sources.	Right. We are not comment of that in our ES	Government of United States of America	Kenya Meteorological Service	Kenya
74897	5	5	5	11	The under representation of key climate mitigation options in climate scenario modelling and intergrated modelling tools could also be atributed to data availability in the form that allows it to be integrated into major emmision sources.	Data availabilty added	Government of United States of America	Kenya Meteorological Service	Kenya
82687	5	9	5	9	"novelty of understanding" is not a clear concept; perhaps better said that there are many empirical data gaps and unknowns about emerging process technologies that often preclude modeling?	Rewording suggested	Miguel Angel Sanjuán	Northwestern University	United States of America
82687	5	9	5	9	"novelty of understanding" is not a clear concept; perhaps better said that there are many empirical data gaps and unknowns about emerging process technologies that often preclude modeling?	Agree	Miguel Angel Sanjuán	Northwestern University	United States of America
57053	5	10	5	10	Should "additional" be added prior to "effective"?	Accepted. Rephrased	Government of Kenya	U.S. Department of State	United States of America
57053	5	10	5	10	Should "additional" be added prior to "effective"?	Agree, or "such"	Government of Kenya	U.S. Department of State	United States of America
14829	5	12	5	13	This statement should be balanced, as electrification is not likely to be the preferred route for heavy industry/emission process/high temperature process such as cement or steel (and which account for the bulk of CO2 emissions from the industry sector - 70% (IEA 2020)). The statement here may lead to a qualitative overestimation of the potential electrification as a mitigation pathway, compared to other core options for heavy industries such as CCUS.	Rejected. IEA NZ among others report shows that much high temperature heating may be provided by electricity	Mariel Vilella	Indépendant consultant	France
14829	5	12	5	13	This statement should be balanced, as electrification is not likely to be the preferred route for heavy industry/emission process/high temperature process such as cement or steel (and which account for the bulk of CO2 emissions from the industry sector - 70% (IEA 2020)). The statement here may lead to a qualitative overestimation of the potential electrification as a mitigation pathway, compared to other core options for heavy industries such as CCUS.	Our assessment indeed shows that electrification is important	Mariel Vilella	Indépendant consultant	France
57055	5	12	5	13	Can authors speak to the role electrification will play once the electric grid is decarbonized for industry? It would likely be a strategy option that plays an important role for all of industry at that point. And, in "other industry", it would be useful for motors and boilers as the authors note later in the chapter.	Accepted	Government of United States of America	U.S. Department of State	United States of America
57055	5	12	5	13	Can authors speak to the role electrification will play once the electric grid is decarbonized for industry? It would likely be a strategy option that plays an important role for all of industry at that point. And, in "other industry", it would be useful for motors and boilers as the authors note later in the chapter.	This is covered in a later statement than can be expanded	Government of United States of America	U.S. Department of State	United States of America
57057	5	12	5	19	It is important to reemphasize that electrification is beneficial when the grid is decarbonized. For example, production of H2 from the grid before that condition is met may actually increase emissions relative to SMR. As a result, it is critical to shift electricity production to zero carbon as quickly as possible, either through on-site renewable generation or grid decarbonization.	Accepted	Yuan Yao	U.S. Department of State	United States of America
57057	5	12	5	19	It is important to reemphasize that electrification is beneficial when the grid is decarbonized. For example, production of H2 from the grid before that condition is met may actually increase emissions relative to SMR. As a result, it is critical to shift electricity production to zero carbon as quickly as possible, either through on-site renewable generation or grid decarbonization.	Important point to add	Yuan Yao	U.S. Department of State	United States of America
14831	5	13	5	14	a carbon free energy carrier' : but only if the electricity is produced from low-carbon sources.	Accepted	Tennant Reed	Indépendant consultant	France
14831	5	13	5	14	a carbon free energy carrier' : but only if the electricity is produced from low-carbon sources.	The carrier in itself is carbon free but section will be revised	Tennant Reed	Indépendant consultant	France
47253	5	13	5	14	Sentence seems written in reverse. Should include " If decarbonized, electricity is a versatile... "	Rejected. Electricity does not carry carbon with it, that´s the point	Government of United States of America	PBL Netherlands Environmental Assessme	Netherlands
47253	5	13	5	14	Sentence seems written in reverse. Should include " If decarbonized, electricity is a versatile... "	Will be revised	Government of United States of America	PBL Netherlands Environmental Assessme	Netherlands
46111	5	15			As the catastrophies with nuclear accidents clearly show nuclear energy is no sustainable low carbon mitigation option for electrification of industrial processes. There is still no long term solution for disposal of waste from nuclear power plants. See our other comments on this issue.	Rejected. There is no agreement with this in the literature and there are many comments to include nuclear as an option	Eleni Kaditi	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety International Climate Policy	Germany
63243	5	15	5	15	Direct use of biomass for process heat is much more efficient than power generation using biomass and then electrification of industrial processes.	Thank you, this has been revised	Government of United States of America	Environment and Climate Change Canada	Canada
57059	5	16	5	19	Grid balancing resources refer to flexible resources that can quickly ramp up and ramp down to keep demand/supply balance in real-time. Maybe authors need to explain why making hydrogen from electrolysis can play this role. If electrolysis only increases electricity consumption during the off-peak to reduce the peak-to-valley difference and if it cannot provide additional power when power is in supply shortage, it is hard to say that it is a substantial grid balancing resource.	Accepted	Constantinos Psomopoulos	U.S. Department of State	United States of America
57059	5	16	5	19	Grid balancing resources refer to flexible resources that can quickly ramp up and ramp down to keep demand/supply balance in real-time. Maybe authors need to explain why making hydrogen from electrolysis can play this role. If electrolysis only increases electricity consumption during the off-peak to reduce the peak-to-valley difference and if it cannot provide additional power when power is in supply shortage, it is hard to say that it is a substantial grid balancing resource.	Add that hydrogen can be reconverted to power	Constantinos Psomopoulos	U.S. Department of State	United States of America
46113	5	20	5	25	To close the loop on carbon dioxide only direct air capture is mentioned, maybe CO2 from biogas included in "use of biomass feedstock". We strongly suggest to mention that also CO2 from processes where the emissions are not avoidable e.g. cement production or some chemical processes (not NH3 production as there CO2 emissions can be avoided by using hydrogen from water electrolysis) can be captured and the CO2 used as a carbon source.	Rejected. Only some options are listed for illustration. We mention several in addition to DAC	Government of United States of America	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety International Climate Policy	Germany
46113	5	20	5	25	To close the loop on carbon dioxide only direct air capture is mentioned, maybe CO2 from biogas included in "use of biomass feedstock". We strongly suggest to mention that also CO2 from processes where the emissions are not avoidable e.g. cement production or some chemical processes (not NH3 production as there CO2 emissions can be avoided by using hydrogen from water electrolysis) can be captured and the CO2 used as a carbon source.	Don´t understand comment. Biomass is mentioned. Can clarify that we need non-fossil sources of carbon (including calcium carbonate)	Government of United States of America	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety International Climate Policy	Germany
47255	5	20	5	21	I am fairly sure that the C element is not contested - it's the origin of where it comes from. Statement makes more of an impression if mentioning something along the use of hydrocarbons of fossil fuels and other possible sources of carbon.	Thanks. Rephrasing suggested	Government of United States of America	PBL Netherlands Environmental Assessme	Netherlands
47255	5	20	5	21	I am fairly sure that the C element is not contested - it's the origin of where it comes from. Statement makes more of an impression if mentioning something along the use of hydrocarbons of fossil fuels and other possible sources of carbon.	Origin will be clarified	Government of United States of America	PBL Netherlands Environmental Assessme	Netherlands
46115	5	22	5	22	Please add "in the future possibly" before chemical recycling. Chemical recycling is not yet a standard state of the art technology and its environmental benefit is not yet proven, therefore it should not be on the same level as mechanical recycling. (References: https://www.umweltbundesamt.de/sites/default/files/medien/5750/publikationen/hgp_chemischesrecycling_englisch_bf.pdf; https://www.vivis.de/wp-content/uploads/WM9/2019_WM_359-370_Quicker.pdf; https://www.nabu.de/imperia/md/content/nabude/abfallpolitik/zwe_jointpaper_understandingenvironmentalimpactsofcr_en.pdf)	Rejected. It says - to reach net zero emissions, so this is about the future. We can not qualify each option all the time in terms of TRL, costs, energy need etc	Government of United States of America	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety International Climate Policy	Germany
46115	5	22	5	22	Please add "in the future possibly" before chemical recycling. Chemical recycling is not yet a standard state of the art technology and its environmental benefit is not yet proven, therefore it should not be on the same level as mechanical recycling. (References: https://www.umweltbundesamt.de/sites/default/files/medien/5750/publikationen/hgp_chemischesrecycling_englisch_bf.pdf; https://www.vivis.de/wp-content/uploads/WM9/2019_WM_359-370_Quicker.pdf; https://www.nabu.de/imperia/md/content/nabude/abfallpolitik/zwe_jointpaper_understandingenvironmentalimpactsofcr_en.pdf)	Reject. Not possible to add nuance on every option	Government of United States of America	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety International Climate Policy	Germany
3643	5	26	5	36	"Costs will be high for primary producers but low for final consumers and general economy" is not necessarily true. "It will likely cost 20-40% more for virgin green steel, but will add below 1-2% on the price for a new car or a new house": Firstly, Alcelor Mittal and estimate green steel will cost 30~80% more expensive in Europe.(https://corporate.arcelormittal.com/sustainability/climate-action-in-europe P7) So 20~40% cost penalty is too optimistic. Secondly, steel is just a material among many other materials and parts for a new car or a house. All other materials such as alminium, glass, plastics, concrete and others would be more expensive of they are to become carbon neutral. In aggregate, cars and houses must be significantly more expensive than suggested 1~2 %.	Rejected. Yes, price effects from different materials will sum up, but at the end of supply chain the share of bacis materials decline and that for labor, services and profits grows, limiting change in the share of materils costs in gross output by a few percent points even when materials prices escalate very significantly. Plus there is matrial substitition and material efficiency effects which mitigate price shocks.	Government of United States of America	JFE Steel Corp.	Japan

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
3643	5	26	5	36	“Costs will be high for primary producers but low for final consumers and general economy” is not necessarily true. “It will likely cost 20-40% more for virgin green steel, but will add below 1-2% on the price for a new car or a new house”: Firstly, Alcelor Mittal and estimate green steel will cost 30~80% more expensive in Europe.(https://corporate.arcelormittal.com/sustainability/climate-action-in-europe P7) So 20~40% cost penalty is too optimistic. Secondly, steel is just a material among many other materials and parts for a new car or a house. All other materials such as alminium, glass, plastics, concrete and others would be more expensive of they are to become carbon neutral. In aggregate, cars and houses must be significantly more expensive than suggested 1~2 %.	Reject. ArcelorMittal is one of many sources and our numbers are from academic literature. We also say "likely"	Government of United States of America	JFE Steel Corp.	Japan
57061	5	26			What is technological capacity?	Accepted	Government of United States of America	U.S. Department of State	United States of America
57061	5	26			What is technological capacity?	Revise: technology options exist, are available or emerging	Government of United States of America	U.S. Department of State	United States of America
77141	5	26	5	36	The claim that abatement is possible at $50-150/tCO2 is untrue; beyond “low hanging” energy efficiency gains, the cost is 1-2 orders of magnitude greater.	Rejected. Given estimated are based on leterature assessment	Philippe Tulkens	Expert Reviewer AR6 SOD WG1	Ireland
77141	5	26	5	36	The claim that abatement is possible at $50-150/tCO2 is untrue; beyond “low hanging” energy efficiency gains, the cost is 1-2 orders of magnitude greater.	Reject, we do say there is variation	Philippe Tulkens	Expert Reviewer AR6 SOD WG1	Ireland
85061	5	28	5	29	The point about sensitivity of costs to uptake policy is extremely important and could be strengthened by the addition of something like the following: "For technologies that exhibit learning rates, costs will fall faster with faster increases in global deployment [optional: "as has been seen with wind, solar PV and battery technologies"]."	Rejected. It is already covered and modular PV and batteries are not a good analogy	JAE YOON LEE	Australian Industry Group	Australia
85061	5	28	5	29	The point about sensitivity of costs to uptake policy is extremely important and could be strengthened by the addition of something like the following: "For technologies that exhibit learning rates, costs will fall faster with faster increases in global deployment [optional: "as has been seen with wind, solar PV and battery technologies"]."	We expect cost reductions in RES-el and H2 more than process technologies but will add learning rates	JAE YOON LEE	Australian Industry Group	Australia
57063	5	30	5	30	Suggest adding "some" before "sectors".	Reject, since it is indeed all sectors (industrial)	Government of United States of America	U.S. Department of State	United States of America
57065	5	31	5	31	Direct costs of what? For specific technologies? If authors are referring to the costs in Table 11.4, these are labeled as "Breakeven" not "Direct" costs. Need to be more clear about what these direct costs are for. Do they cover the 5-15 years of intensive innovation, commercialization, and policy or are they initial investment costs?	Accepted	Government of United States of America	U.S. Department of State	United States of America
57065	5	31	5	31	Direct costs of what? For specific technologies? If authors are referring to the costs in Table 11.4, these are labeled as "Breakeven" not "Direct" costs. Need to be more clear about what these direct costs are for. Do they cover the 5-15 years of intensive innovation, commercialization, and policy or are they initial investment costs?	Thanks, this is abatement costs	Government of United States of America	U.S. Department of State	United States of America
57067	5	31	5	31	"direct" not "directs" costs	Accepted	Suyi Kim	U.S. Department of State	United States of America
57067	5	31	5	31	"direct" not "directs" costs	Thanks	Suyi Kim	U.S. Department of State	United States of America
85059	5	31	5	31	Remove errant 's' from "Directs costs..."	Accepted	JAE YOON LEE	Australian Industry Group	Australia
43951	5	33	5	36	The statement that the "focused costs on producers translate to much smaller increases for intermediate manufacturers and final consumers" assumes that producers will absorb all costs of decarbonization. This would substantially increase the costs of manufacturers cement domestically and result in significant leakage. These leakage impacts would have a negative impact on the overall world climate because if the U.S. cement industry shuts down due to the lack of competitiveness, imports from less carbon constrained countries will dominate.	Rejected. The point is opposite on cost pass throught along the supply chain. The trade/competitiveness has been already covered in the fourth statement, above	Government of Republic of Korea	Portland Cement Association	United States of America
43951	5	33	5	36	The statement that the "focused costs on producers translate to much smaller increases for intermediate manufacturers and final consumers" assumes that producers will absorb all costs of decarbonization. This would substantially increase the costs of manufacturers cement domestically and result in significant leakage. These leakage impacts would have a negative impact on the overall world climate because if the U.S. cement industry shuts down due to the lack of competitiveness, imports from less carbon constrained countries will dominate.	No, this means that costs are passed through to consumers. Carbon leakage risks is dealt with in the final part of teh ES	Government of Republic of Korea	Portland Cement Association	United States of America
11481	5	34	5	36	The source of the statement "it will likely cost 20–40% more for virgin green steel, 5–10% for steel parts, but will add below 1–2% on the price for a new car or a new house, based on higher costs for steel and cement respectively" cannot be identified in the main text. Please check.	Rejected. There is figure 11.10 which present this	Government of Saudi Arabia	Hong Kong Observatory	China
11481	5	34	5	36	The source of the statement "it will likely cost 20–40% more for virgin green steel, 5–10% for steel parts, but will add below 1–2% on the price for a new car or a new house, based on higher costs for steel and cement respectively" cannot be identified in the main text. Please check.	Thanks we will check line-of-sight for these numbers (based on Rootzen for cars and buildings)	Government of Saudi Arabia	Hong Kong Observatory	China
3645	5	37	5	44	“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.” This must be a quotation from IEA’s steel roadmap. But there is no convincing description on “how” those can be possible.	Rejected. Chapter lists the measures needed for this	Government of United States of America	JFE Steel Corp.	Japan
3645	5	37	5	44	“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.” This must be a quotation from IEA’s steel roadmap. But there is no convincing description on “how” those can be possible.	ES does not allow elaboration of how but this will follow in the chapter, different parts	Government of United States of America	JFE Steel Corp.	Japan
15557	5	41	5	44	When stating that CCU will be required to decarbonize the production of steel, this is not quite right. CCS can decarbonize the production of steel by removing the CO2 of the flue gas coming out of the blast furnace (for example), but utlizing carbon dioxide to produce steel is technically infeasible, thus it cannot decarbonize the production. However, utilizing CO2 emitted by the iron & steel industry by mineralizing it with steel slags could reduce the cost of CCS in steel industry and avoid the emissions of CO2.	Taken into account	Rebecca Dell	MINES ParisTech, Total	France
15557	5	41	5	44	When stating that CCU will be required to decarbonize the production of steel, this is not quite right. CCS can decarbonize the production of steel by removing the CO2 of the flue gas coming out of the blast furnace (for example), but utlizing carbon dioxide to produce steel is technically infeasible, thus it cannot decarbonize the production. However, utilizing CO2 emitted by the iron & steel industry by mineralizing it with steel slags could reduce the cost of CCS in steel industry and avoid the emissions of CO2.	This refers to CCU on off-gasses and will be clarified	Rebecca Dell	MINES ParisTech, Total	France
60477	5	41	5	44	CO2-based fuels / e-fuels should be added together with H2 in this sentence. Moreover the role of CCU should be stated independantly of CCS, because the sentence is scientifically inccorect. CCU is one of the few option to decarbonise/deffosilise the steel-industry, but again it does not have the same role as CCS, because it allows to create valuable product using CO2 as a feedstock and CCU technologies are drop-in solutions to decrease net CO2 emissions rapidly and then to reach net-zero or even negative emissions when it comes to Direct Air Capture and mineralisation .One (amongst others) typical example of this is the project Carbon2Chem (Wich et al., 2020: https://www.frontiersin.org/articles/10.3389/fenrg.2019.00162/full_) or the EU-funded project INITIATE that aims to valorise the flue gas of the steel industry to create fertlisers. (https://www.tno.nl/en/focus-areas/energy-transition/roadmaps/towards-co2-neutral-industry/reducing-co2-emissions-through-capture-use-and-storage/reduce-emissions-steel-industry/). Or the project Steelanol (http://www.steelanol.eu/en) that recycle carbon into sustainable bio-ethanol. The CO2 to mineralisation path is also an interesting option to decarbonise/deffosilise the steel industry (e.g.SAPEA 2018, Ramboll 2019) . Di Maria et al., 2020 conducted an LCA of carbonated steel slag including CO2 capture and confirm that mineralization 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. •Di Maria et al, 2020, International Journal of Greenhouse Gas Control, 93. * Ramboll, the Institute for Advanced Sustainability Studies, CESR– Center for Environmental Systems Research at the University of Kassel, CEDelft, and IOM Law January – 2019•SAPEA, 2018, Science Advice for Policy by EU Academies, Novel Carbon Capture and Utilisation Technologies-Research and Climate Aspects, Evidence Review Report, 2 •Wich et al. 2020, Frontiers Energy Research, 7, 162.	Reject, CCU such as Carbon2Chem does not result in very low or near zero emissions	Philippe Tulkens	Université Libre de Bruxelles / CO2 Value Europe	Belgium
60477	5	41	5	44	CO2-based fuels / e-fuels should be added together with H2 in this sentence. Moreover the role of CCU should be stated independantly of CCS, because the sentence is scientifically inccorect. CCU is one of the few option to decarbonise/deffosilise the steel-industry, but again it does not have the same role as CCS, because it allows to create valuable product using CO2 as a feedstock and CCU technologies are drop-in solutions to decrease net CO2 emissions rapidly and then to reach net-zero or even negative emissions when it comes to Direct Air Capture and mineralisation .One (amongst others) typical example of this is the project Carbon2Chem (Wich et al., 2020: https://www.frontiersin.org/articles/10.3389/fenrg.2019.00162/full_) or the EU-funded project INITIATE that aims to valorise the flue gas of the steel industry to create fertlisers. (https://www.tno.nl/en/focus-areas/energy-transition/roadmaps/towards-co2-neutral-industry/reducing-co2-emissions-through-capture-use-and-storage/reduce-emissions-steel-industry/). Or the project Steelanol (http://www.steelanol.eu/en) that recycle carbon into sustainable bio-ethanol. The CO2 to mineralisation path is also an interesting option to decarbonise/deffosilise the steel industry (e.g.SAPEA 2018, Ramboll 2019) . Di Maria et al., 2020 conducted an LCA of carbonated steel slag including CO2 capture and confirm that mineralization 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. •Di Maria et al, 2020, International Journal of Greenhouse Gas Control, 93. * Ramboll, the Institute for Advanced Sustainability Studies, CESR– Center for Environmental Systems Research at the University of Kassel, CEDelft, and IOM Law January – 2019•SAPEA, 2018, Science Advice for Policy by EU Academies, Novel Carbon Capture and Utilisation Technologies-Research and Climate Aspects, Evidence Review Report, 2 •Wich et al. 2020, Frontiers Energy Research, 7, 162.	We partly agree and CCU will be dealt with with more caution and nuance but it should be noted that carbon2chem does not lead to zero emissions. Hydrogen is listed as an example and not all examples can be listed in every place.	Philippe Tulkens	Université Libre de Bruxelles / CO2 Value Europe	Belgium
83721	5	41	5	44	CO2-based fuels / e-fuels should be added together with H2 in this sentence. Moreover the role of CCU should be stated independantly of CCS, because the sentence is scientifically inccorect. CCU is one of the few option to decarbonise/deffosilise the steel-industry, but again it does not have the same role as CCS, because it allows to create valuable product using CO2 as a feedstock and CCU technologies are drop-in solutions to decrease net CO2 emissions rapidly and then to reach net-zero or even negative emissions when it comes to Direct Air Capture and mineralisation .One (amongst others) typical example of this is the project Carbon2Chem (Wich et al., 2020: https://www.frontiersin.org/articles/10.3389/fenrg.2019.00162/full_) or the EU-funded project INITIATE that aims to valorise the flue gas of the steel industry to create fertlisers. (https://www.tno.nl/en/focus-areas/energy-transition/roadmaps/towards-co2-neutral-industry/reducing-co2-emissions-through-capture-use-and-storage/reduce-emissions-steel-industry/). Or the project Steelanol (http://www.steelanol.eu/en) that recycle carbon into sustainable bio-ethanol. The CO2 to mineralisation path is also an interesting option to decarbonise/deffosilise the steel industry (e.g.SAPEA 2018, Ramboll 2019) . Di Maria et al., 2020 conducted an LCA of carbonated steel slag including CO2 capture and confirm that mineralization 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. •Di Maria et al, 2020, International Journal of Greenhouse Gas Control, 93. * Ramboll, the Institute for Advanced Sustainability Studies, CESR– Center for Environmental Systems Research at the University of Kassel, CEDelft, and IOM Law January – 2019•SAPEA, 2018, Science Advice for Policy by EU Academies, Novel Carbon Capture and Utilisation Technologies-Research and Climate Aspects, Evidence Review Report, 2 •Wich et al. 2020, Frontiers Energy Research, 7, 162.	Reject, identical comment to previous	Government of United States of America	LUT University	Finland

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
83721	5	41	5	44	CO2-based fuels / e-fuels should be added together with H2 in this sentence. Moreover the role of CCU should be stated independantly of CCS, because the sentence is scientifically inccorect. CCU is one of the few option to decarbonise/deffosilise the steel-industry, but again it does not have the same role as CCS, because it allows to create valuable product using CO2 as a feedstock and CCU technologies are drop-in solutions to decrease net CO2 emissions rapidly and then to reach net-zero or even negative emissions when it comes to Direct Air Capture and mineralisation .One (amongst others) typical example of this is the project Carbon2Chem (Wich et al., 2020: https://www.frontiersin.org/articles/10.3389/fenrg.2019.00162/full_) or the EU-funded project INITIATE that aims to valorise the flue gas of the steel industry to create fertlisers. (https://www.tno.nl/en/focus-areas/energy-transition/roadmaps/towards-co2-neutral-industry/reducing-co2-emissions-through-capture-use-and-storage/reduce-emissions-steel-industry/). Or the project Steelanol (http://www.steelanol.eu/en) that recycle carbon into sustainable bio-ethanol. The CO2 to mineralisation path is also an interesting option to decarbonise/deffosilise the steel industry (e.g.SAPEA 2018, Ramboll 2019) . Di Maria et al., 2020 conducted an LCA of carbonated steel slag including CO2 capture and confirm that mineralization 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. •Di Maria et al, 2020, International Journal of Greenhouse Gas Control, 93. * Ramboll, the Institute for Advanced Sustainability Studies, CESR– Center for Environmental Systems Research at the University of Kassel, CEDelft, and IOM Law January – 2019•SAPEA, 2018, Science Advice for Policy by EU Academies, Novel Carbon Capture and Utilisation Technologies-Research and Climate Aspects, Evidence Review Report, 2 •Wich et al. 2020, Frontiers Energy Research, 7, 162.	Identical commen as above	Government of United States of America	LUT University	Finland
14835	5	42	5	43	Fuel switching also includes biomass (as hydrogen is not likely to be a fuel switching option for the retrofit of BF-BOF, but rather for DRI).	Accepted	Antoine BONDUELLE	Indépendant consultant	France
14835	5	42	5	43	Fuel switching also includes biomass (as hydrogen is not likely to be a fuel switching option for the retrofit of BF-BOF, but rather for DRI).	biomass can be added	Antoine BONDUELLE	Indépendant consultant	France
57069	5	45	5	47	To what do "former" and "latter" refer?	Edited for clarity.	Government of United States of America	U.S. Department of State	United States of America
57069	5	45	5	47	To what do "former" and "latter" refer?	Rephrasing suggested	Government of United States of America	U.S. Department of State	United States of America
57069	5	45	5	47	To what do "former" and "latter" refer?	refers to options. Will be clarified	Government of United States of America	U.S. Department of State	United States of America
77143	5	45	6	7	The chapter contains multiple references to cement production. The authors should be aware that the Global Cement and Concrete Association has committed to a "Net-Zero Concrete" by 2050 – see https://gccassociation.org/climate-ambition/. Also, the European Cement Association has produced a similar more detailed roadmap – see https://lowcarboneconomy.cembureau.eu/carbon-neutrality/. Both ambitions may significant assumptions on technology development, availability of alternative fuels, enabling legislation, etc, and are uncosted. See comment #12.	Those materials were used in developing figure 11.10	Government of Kenya	Expert Reviewer AR6 SOD WG1	Ireland
77143	5	45	6	7	The chapter contains multiple references to cement production. The authors should be aware that the Global Cement and Concrete Association has committed to a "Net-Zero Concrete" by 2050 – see https://gccassociation.org/climate-ambition/. Also, the European Cement Association has produced a similar more detailed roadmap – see https://lowcarboneconomy.cembureau.eu/carbon-neutrality/. Both ambitions may significant assumptions on technology development, availability of alternative fuels, enabling legislation, etc, and are uncosted. See comment #12.	Thank you, we are aware of these committment and may add references in section 11.6	Government of Kenya	Expert Reviewer AR6 SOD WG1	Ireland
14993	5	47	6	7	This paragraph should be completely redrafted to consistent with chapter 11.4.1.2 since there is no consistency.	Unclear comment	Philippe Tulkens	Japan Cement Association	Japan
14993	5	47	6	7	This paragraph should be completely redrafted to consistent with chapter 11.4.1.2 since there is no consistency.	Line of sight will be checked to ensure consistency	Philippe Tulkens	Japan Cement Association	Japan
85063	5	47	6	1	Suggest modifying this sentence to better articulate the issue as follows: "Cement and concrete are currently overused because they are inexpensive, durable and ubiquitous, and consumption decisions typically do not give weight to their production emissions."	Used, thank you.	Government of United States of America	Australian Industry Group	Australia
85063	5	47	6	1	Suggest modifying this sentence to better articulate the issue as follows: "Cement and concrete are currently overused because they are inexpensive, durable and ubiquitous, and consumption decisions typically do not give weight to their production emissions."	Accepted	Government of United States of America	Australian Industry Group	Australia
3515	6	2	6	2	It should be "concrete" instead of "cement".	Accepted		IECA	Spain
3515	6	2	6	2	It should be "concrete" instead of "cement".	Thanks, correct		IECA	Spain
3517	6	2	6	2	Add after "...aggregates...": "...adequate cement selection and concrete mix design to optimise carbon uptake and enhance durability)".	Our available literature does not directly support this.		IECA	Spain
3517	6	2	6	2	Add after "...aggregates...": "...adequate cement selection and concrete mix design to optimise carbon uptake and enhance durability)".	Accepted		IECA	Spain
3517	6	2	6	2	Add after "...aggregates...": "...adequate cement selection and concrete mix design to optimise carbon uptake and enhance durability)".	Thanks, will amend		IECA	Spain
10405	6	2	6	2	It should be "concrete" instead of "cement".	Accepted		Oficemen	Spain
10405	6	2	6	2	It should be "concrete" instead of "cement".	See above. Same comment		Oficemen	Spain
10407	6	2	6	2	Add after "...aggregates...": "...adequate cement selection and concrete mix design to optimise carbon uptake and enhance durability)".	Our available literature does not directly support this.		Oficemen	Spain
10407	6	2	6	2	Add after "...aggregates...": "...adequate cement selection and concrete mix design to optimise carbon uptake and enhance durability)".	Rejected. Too detailed for ES		Oficemen	Spain
10407	6	2	6	2	Add after "...aggregates...": "...adequate cement selection and concrete mix design to optimise carbon uptake and enhance durability)".	See above. Same comment		Oficemen	Spain
11561	6	2	6	2	It should be "concrete" instead of "cement".	Accepted		UNIVERSITY	Spain
11561	6	2	6	2	It should be "concrete" instead of "cement".	See above. Same comment		UNIVERSITY	Spain
11563	6	2	6	2	Add after "...aggregates...": "...adequate cement selection and concrete mix design to optimise carbon uptake and enhance durability)".	Our available literature does not directly support this.		UNIVERSITY	Spain
11563	6	2	6	2	Add after "...aggregates...": "...adequate cement selection and concrete mix design to optimise carbon uptake and enhance durability)".	Accepted		UNIVERSITY	Spain
11563	6	2	6	2	Add after "...aggregates...": "...adequate cement selection and concrete mix design to optimise carbon uptake and enhance durability)".	See above. Same comment		UNIVERSITY	Spain
82689	6	2	6	2	do you mean well-made concrete? cement + aggregates+water = concrete, but here you imply that "well-made cement" includes aggregates?	Accepted		Northwestern University	United States of America
82689	6	2	6	2	do you mean well-made concrete? cement + aggregates+water = concrete, but here you imply that "well-made cement" includes aggregates?	See above. Same comment		Northwestern University	United States of America
82691	6	2	6	2	"where it is needed" seems to imply materials efficiency but if so it oversimplifies the concept of materials efficiency, which means right-sized components, post-tensioned slabs, performance-based concretes, etc. Perhaps better to elaborate more here since "where it is needed" doesn't give sufficient detail at the executive summary to give justice to this important concept?	Included in editing		Northwestern University	United States of America
82691	6	2	6	2	"where it is needed" seems to imply materials efficiency but if so it oversimplifies the concept of materials efficiency, which means right-sized components, post-tensioned slabs, performance-based concretes, etc. Perhaps better to elaborate more here since "where it is needed" doesn't give sufficient detail at the executive summary to give justice to this important concept?	Rejected. Too detailed for ES		Northwestern University	United States of America
82691	6	2	6	2	"where it is needed" seems to imply materials efficiency but if so it oversimplifies the concept of materials efficiency, which means right-sized components, post-tensioned slabs, performance-based concretes, etc. Perhaps better to elaborate more here since "where it is needed" doesn't give sufficient detail at the executive summary to give justice to this important concept?	Section will be revised.		Northwestern University	United States of America
43953	6	3	6	7	I appreciate IPCC recognition that 60% of the cement industry's emissions are from calcination, which can best be addressed through implementation of economically scalable CCUS technologies. However, not all combustion emissions can be eliminated through fuel switching. CCUS is crucial for the cement industry since neither fuel switching nor energy efficiency address the chemical release of process emissions during the manufacturing process.	Thank you, this is expanded upon in the main text.		Portland Cement Association	United States of America
43953	6	3	6	7	I appreciate IPCC recognition that 60% of the cement industry's emissions are from calcination, which can best be addressed through implementation of economically scalable CCUS technologies. However, not all combustion emissions can be eliminated through fuel switching. CCUS is crucial for the cement industry since neither fuel switching nor energy efficiency address the chemical release of process emissions during the manufacturing process.	Thanks		Portland Cement Association	United States of America
43953	6	3	6	7	I appreciate IPCC recognition that 60% of the cement industry's emissions are from calcination, which can best be addressed through implementation of economically scalable CCUS technologies. However, not all combustion emissions can be eliminated through fuel switching. CCUS is crucial for the cement industry since neither fuel switching nor energy efficiency address the chemical release of process emissions during the manufacturing process.	Thank you. May amend to make this very clear and include the sponge effect		Portland Cement Association	United States of America
43221	6	4	6	6	The waste that is sent to be burnt in cement plants is highly heterogeneous and it normally contains a high proportion of plastic which is of fossil origin. There is no system to separate fossil components from non-fossil ones. In short, the concept of fossil-fee waste fuel is not credible, not quoting any source, it does not exist as a product in the market of waste management.	Accepted		Zero Waste Europe/University of Manchester	United Kingdom (of Great Britain and Northern Ireland)
43221	6	4	6	6	The waste that is sent to be burnt in cement plants is highly heterogeneous and it normally contains a high proportion of plastic which is of fossil origin. There is no system to separate fossil components from non-fossil ones. In short, the concept of fossil-fee waste fuel is not credible, not quoting any source, it does not exist as a product in the market of waste management.	Disagree. There is wood waste		Zero Waste Europe/University of Manchester	United Kingdom (of Great Britain and Northern Ireland)
57071	6	4	6	7	Reads as if it is a lot easier for cement/concrete industry to use biomass, fossil-fuel waste fuel (what is that? an example?), and switch to produce cement from purely electricity and hydrogen, compared to new chemistries in cement making. These two sentences state that it will take a long time for new chemistry cement products to be commercialized, while it seems to imply that electrification and hydrogen use in cement will not be that long, which might not be the case.	Thank you for your comment, but we are unsure of your argument.		U.S. Department of State	United States of America
57071	6	4	6	7	Reads as if it is a lot easier for cement/concrete industry to use biomass, fossil-fuel waste fuel (what is that? an example?), and switch to produce cement from purely electricity and hydrogen, compared to new chemistries in cement making. These two sentences state that it will take a long time for new chemistry cement products to be commercialized, while it seems to imply that electrification and hydrogen use in cement will not be that long, which might not be the case.	Section will be revised to accomodate several comments		U.S. Department of State	United States of America
57073	6	5	6	5	The text mentioned "fossil-fuel waste fuel" in cement and concrete making. Give an example of fossil-fuel waste fuel.	Removed		U.S. Department of State	United States of America
57073	6	5	6	5	The text mentioned "fossil-fuel waste fuel" in cement and concrete making. Give an example of fossil-fuel waste fuel.	Reference to waste will be removed		U.S. Department of State	United States of America
49763	6	6	6	6	It should not be of high confidence in view of the task stated in the following lines (7-13), which is cost intensive and difficult to adopt in developing countries and that is why the industrial emission is growing faster since year 2000 than any other sector (line 14-15). Line 43-45 also says that Net zero emission can be achieved by the year 2050 by deploying multiple available option (medium confidence) and accordingly, line 6 should not be of high confidence	Nowhere is it stated that this is of high confidence.		CSIR-CIMFR, Dhanbad	India
49763	6	6	6	6	It should not be of high confidence in view of the task stated in the following lines (7-13), which is cost intensive and difficult to adopt in developing countries and that is why the industrial emission is growing faster since year 2000 than any other sector (line 14-15). Line 43-45 also says that Net zero emission can be achieved by the year 2050 by deploying multiple available option (medium confidence) and accordingly, line 6 should not be of high confidence	Do you mean line 8? The confidence statement applies.		CSIR-CIMFR, Dhanbad	India
57075	6	6	6	6	Certain cement companies are using select minerals to replace a portion of the limestone in the kiln. This eliminates a portion of the CO2 if the replacement material does not release CO2.	Fixed, thank you for pointing this omission out - it is in 11.3.6 & 11.4.1		U.S. Department of State	United States of America
57075	6	6	6	6	Certain cement companies are using select minerals to replace a portion of the limestone in the kiln. This eliminates a portion of the CO2 if the replacement material does not release CO2.	Section will be revised to accomodate several comments and include the option of substitution/slag/ashes		U.S. Department of State	United States of America
82693	6	6	6	7	would suggest saying commercialized AND/OR accepted, since some new chemistries (notably Solidia) are already on the market	Solidia reduces emissions by 30%. Adding CO2 deepens this, but reduces recarbonation potential		Northwestern University	United States of America
82693	6	6	6	7	would suggest saying commercialized AND/OR accepted, since some new chemistries (notably Solidia) are already on the market	Section will be revised to accomodate this comment		Northwestern University	United States of America
47257	6	9	6	11	Sentence could improve with the addition of "ceteris paribus/ with all conditions held constant" (assuming static carbon price)	Thanks. Rephrased		PBL Netherlands Environmental Assessme	Netherlands

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
47257	6	9	6	11	Sentence could improve with the addition of "ceteris paribus/ with all conditions held constant" (assuming static carbon price)	Thanks, this point will be included		PBL Netherlands Environmental Assessme	Netherlands
43223	6	13	6	16	Plastic waste is made of fossil carbon and therefore highly carbon-intensive and a type of combustion that is rather a net contributor to climate change. Combustion of plastic waste is also a highly polluting process so it does harm other environmental, SDG objectives. The idea that plastic waste should be burnt for climate mitigation pruposes should be deleted.	Rejected. We do not say that plastic waste should be incinerated		Zero Waste Europe/University of Manchester	United Kingdom (of Great Britain and Northern Ireland)
43223	6	13	6	16	Plastic waste is made of fossil carbon and therefore highly carbon-intensive and a type of combustion that is rather a net contributor to climate change. Combustion of plastic waste is also a highly polluting process so it does harm other environmental, SDG objectives. The idea that plastic waste should be burnt for climate mitigation pruposes should be deleted.	We do not suggest this		Zero Waste Europe/University of Manchester	United Kingdom (of Great Britain and Northern Ireland)
57077	6	13	6	16	Biomass is not only limited due to competition for land for food production, biodiversity, and land use negative carbon sinks. Biomass resources are also becoming increasingly scarce because multiple applications that all use biomass as feedstock or fuel compete for these resources. There are examples of increasing the use of biomass in the steel industry, e.g., from Brazil in the form of biochar. Biochar can be converted to a higher purpose of sequestering more carbon if used in agricultural soils. Using it in steel production may not make the most economic and climate sense. Also, according to NRDC (https://www.nrdc.org/experts/sasha-stashwick/nrdc-releases-new-fact-sheet-biochar), there remains a great deal of uncertainty with respect to the environmental and economic performance of different biochar production pathways, as well as key environmental risks associated with the production and use of biochar.	Good point be we cannot elaborate details om biomass and land use here		U.S. Department of State	United States of America
57077	6	13	6	16	Biomass is not only limited due to competition for land for food production, biodiversity, and land use negative carbon sinks. Biomass resources are also becoming increasingly scarce because multiple applications that all use biomass as feedstock or fuel compete for these resources. There are examples of increasing the use of biomass in the steel industry, e.g., from Brazil in the form of biochar. Biochar can be converted to a higher purpose of sequestering more carbon if used in agricultural soils. Using it in steel production may not make the most economic and climate sense. Also, according to NRDC (https://www.nrdc.org/experts/sasha-stashwick/nrdc-releases-new-fact-sheet-biochar), there remains a great deal of uncertainty with respect to the environmental and economic performance of different biochar production pathways, as well as key environmental risks associated with the production and use of biochar.	Thank you. No need to explain here why it is limited or scarce		U.S. Department of State	United States of America
82695	6	15	6	15	in A low carbon world	Thanks!		Northwestern University	United States of America
57079	6	17	6	19	Agree but it helps to consider the source of electricity in the future. Light industry has a great opportunity to decarbonize as in the U.S. it is powered mainly by natural gas and electricity (from a fossil fueled electric grid). Energy efficiency, renewable energy, and electrification should have an impact on decarbonizing this portion of the industrial sector although electrification will be most valuable after the grid decarbonizes. U.S. EIA AEO estimates show light industry growing at higher rates than energy intensive sectors.	Thanks, source of electricity clarified		U.S. Department of State	United States of America
57079	6	17	6	19	Agree but it helps to consider the source of electricity in the future. Light industry has a great opportunity to decarbonize as in the U.S. it is powered mainly by natural gas and electricity (from a fossil fueled electric grid). Energy efficiency, renewable energy, and electrification should have an impact on decarbonizing this portion of the industrial sector although electrification will be most valuable after the grid decarbonizes. U.S. EIA AEO estimates show light industry growing at higher rates than energy intensive sectors.	Whole ES should be clear about source and grid emission factors		U.S. Department of State	United States of America
57081	6	17	6	19	Unlike other sections in the Executive Summary, this section does not have any text to support the claim. Authors may want to elaborate on this statement to explain that light industry typically has processes that do not require high temperature heat. A wider range of commercialized technology exists for providing lower temperature heat to support these processes.	Low temp now mentioned and bullet is elaborated		U.S. Department of State	United States of America
57081	6	17	6	19	Unlike other sections in the Executive Summary, this section does not have any text to support the claim. Authors may want to elaborate on this statement to explain that light industry typically has processes that do not require high temperature heat. A wider range of commercialized technology exists for providing lower temperature heat to support these processes.	Yes, agree		U.S. Department of State	United States of America
69855	6	17	6	19	I would quote "electro-magnetic" technologies (rather than "electrothermal") and add the option of compact heat storage to turn variable renewable electricity supply into constant superheated air or steam.	Rejected. Electrothermal highlights thermal which is most important. Mentioning heat storage is too much detail		Institut Français des Relations Internationales	France
69855	6	17	6	19	I would quote "electro-magnetic" technologies (rather than "electrothermal") and add the option of compact heat storage to turn variable renewable electricity supply into constant superheated air or steam.	Electrothermal is the common umbrella term to denominate IR, Microwave, UV, induction heating etc.		Institut Français des Relations Internationales	France
82697	6	17	6	19	At the executive summary level, it would be good to elaborate more here. Are there particular "light industries" that are more important (e.g., semiconductor manufacturing in a digitalizing world)? Are there particular technologies that are most impactful (e.g., electric boilers, resistance heaters, etc.)? This is the only ES statement with no further details, but it would be important to elaborate since there are significant challenges to decarbonizing the "light industries" too (many more smaller plants w/o deep pockets for investments, etc.)	Rejected. This sector is so incredibly diverse so it is not possible to provide detail in a fair and balanced way		Northwestern University	United States of America
82697	6	17	6	19	At the executive summary level, it would be good to elaborate more here. Are there particular "light industries" that are more important (e.g., semiconductor manufacturing in a digitalizing world)? Are there particular technologies that are most impactful (e.g., electric boilers, resistance heaters, etc.)? This is the only ES statement with no further details, but it would be important to elaborate since there are significant challenges to decarbonizing the "light industries" too (many more smaller plants w/o deep pockets for investments, etc.)	This will be elaborated		Northwestern University	United States of America
46117	6	20	132	31	The access to biomass is limited also in the pulp and paper industry. Only virgin fibre production has access to bark and lignine residues of the pulp production in a sufficient amount. The production of recycled paper from waste paper on the other hand does still rely widely on fossil fuels. Also sustainable sourced biomass (wood) will run short. Aspects of loss of biodiversity and the storage and sink functions of forest shave to be taken into account with more care. For non integrated mills and the paper recycling industry the production of CO2 neutral process heat is a challenge. Techniques used are heat pumps, heat exchanger, electricity, geothermal heat, biomass. Please see also for energy demand of the pulp and paper production: https://eippcb.jrc.ec.europa.eu/reference/production-pulp-paper-and-board; https://www.iea.org/reports/pulp-and-paper; https://www.umweltbundesamt.de/publikationen/germany-in-2050-a-greenhouse-gas-neutral-country, chapter pulp and paper industry	The level of detail indicated in this comment is not possible in the ES but can be found in the chapter		Federal Ministry for the Environment, Nature Conservation and Nuclear Safety International Climate Policy	Germany
46117	6	20	132	31	The access to biomass is limited also in the pulp and paper industry. Only virgin fibre production has access to bark and lignine residues of the pulp production in a sufficient amount. The production of recycled paper from waste paper on the other hand does still rely widely on fossil fuels. Also sustainable sourced biomass (wood) will run short. Aspects of loss of biodiversity and the storage and sink functions of forest shave to be taken into account with more care. For non integrated mills and the paper recycling industry the production of CO2 neutral process heat is a challenge. Techniques used are heat pumps, heat exchanger, electricity, geothermal heat, biomass. Please see also for energy demand of the pulp and paper production: https://eippcb.jrc.ec.europa.eu/reference/production-pulp-paper-and-board; https://www.iea.org/reports/pulp-and-paper; https://www.umweltbundesamt.de/publikationen/germany-in-2050-a-greenhouse-gas-neutral-country, chapter pulp and paper industry	Thanks. This will be revised to include heat options		Federal Ministry for the Environment, Nature Conservation and Nuclear Safety International Climate Policy	Germany
57083	6	20			Clarify "close access" terminology. It is unclear what this means.	Clarified now		U.S. Department of State	United States of America
57083	6	20			Clarify "close access" terminology. It is unclear what this means.	Thanks, will clarify		U.S. Department of State	United States of America
63245	6	20	6	24	Pulp and paper can become a net-negative sector through the implementation of BECCS and will likely see the first adoption of BECCS because pulp and paper mills are the largest point sources of biogenic CO2. BECCS plays a significant in several long-term scenarios presented in Chap. 3 and its integration with the pulp and paper sector should be acknowledged.	Accepted		Environment and Climate Change Canada	Canada
63245	6	20	6	24	Pulp and paper can become a net-negative sector through the implementation of BECCS and will likely see the first adoption of BECCS because pulp and paper mills are the largest point sources of biogenic CO2. BECCS plays a significant in several long-term scenarios presented in Chap. 3 and its integration with the pulp and paper sector should be acknowledged.	Thanks, we will note P&P as a source of biogenic carbon for various purposes		Environment and Climate Change Canada	Canada
57085	6	21	6	23	This is not necessarily true and should be caveated: "The pulp and paper industry is energy intensive but not a large direct emitter if it uses sustainably sourced feedstock and bioenergy rather than fossil fuels." It is a large direct emitter BUT in cases where entities use residues or materials with no alternative market/use, these emissions may be offset to some degree. Just because something is sustainably produced does not mean it should be treated as carbon neutral.	Rejected. We agree in principle but sustainably sources implies carbon neutrality (replanting etc). The fact that biomass residues could replace fossil fuels elsewhere is a too far reaching and complex arguement for the ES		U.S. Department of State	United States of America
57085	6	21	6	23	This is not necessarily true and should be caveated: "The pulp and paper industry is energy intensive but not a large direct emitter if it uses sustainably sourced feedstock and bioenergy rather than fossil fuels." It is a large direct emitter BUT in cases where entities use residues or materials with no alternative market/use, these emissions may be offset to some degree. Just because something is sustainably produced does not mean it should be treated as carbon neutral.	Thanks, this will be clarified. They have large biogenic emissions		U.S. Department of State	United States of America
57087	6	21	6	23	The text here is not supported by main text in chapter. There is nothing in the pulp and paper section (11.4.1.4) that discusses or even mentions the use of sustainably sourced feedstock. The current summary language should be removed, as it doesn't align with chapter and overall is incorrect anyway. Section 11.4.1.4 is more balanced and accurate, and should be used to inform this summary.	Accepted. Both ES and 11.4.1.4 revised to be coordinated		U.S. Department of State	United States of America
57087	6	21	6	23	The text here is not supported by main text in chapter. There is nothing in the pulp and paper section (11.4.1.4) that discusses or even mentions the use of sustainably sourced feedstock. The current summary language should be removed, as it doesn't align with chapter and overall is incorrect anyway. Section 11.4.1.4 is more balanced and accurate, and should be used to inform this summary.	Thanks for this observation. We will revise		U.S. Department of State	United States of America
52565	6	32	6	39	Box11.1 mentioned the geographical distribution of both "green" and "blue" hydrogen, thus both of them should be included and not singling out only "green" hydrogen.	Rejected and accepted. Other sources and CCS is already mentioned. Green has been deleted		Sustainability Advisor to the Minister Ministry of Petroleum and Mineral	Saudi Arabia
52565	6	32	6	39	Box11.1 mentioned the geographical distribution of both "green" and "blue" hydrogen, thus both of them should be included and not singling out only "green" hydrogen.	Thanks. Delete green or add blue?		Sustainability Advisor to the Minister Ministry of Petroleum and Mineral	Saudi Arabia
57089	6	32	6	39	It may be important to consider whether local production of H2 from zero-carbon electricity may be preferable to transportation of H2 over long distances due to infrastructure costs and losses in transport and storage.	Rejected. We think the wording already speaks to this point		U.S. Department of State	United States of America
57089	6	32	6	39	It may be important to consider whether local production of H2 from zero-carbon electricity may be preferable to transportation of H2 over long distances due to infrastructure costs and losses in transport and storage.	Reject. You are right of course but the emphasis is on hydrogen carriers and assuming there are regions where local production is not attractive		U.S. Department of State	United States of America
74237	6	32	6	39	This paragraph should be revised so that it is not renewables centric. Green hydrogen produced by carbon free nuclear is exactly the same as hydrogen produced by renewables. The point is to manufacture hydrogen using carbon free energy. Additionally, due to its energy density, nuclear can produce significantly more hydrogen with a smaller geographical footprint.	Reject. This talks about how geographies may be reshaped. In principle you are right about purple hydrogen but NP costs are too high. This belongs in Ch 6		Pillsbury Law Firm	United States of America
82699	6	43	6	43	It's not clear what you mean by "demand management" here ... do you mean demand response/load shifting? The term "demand management" here also creates confusion since in the preceding sentence you say DSM programs are well-established.	Thanks. Amended		Northwestern University	United States of America
82699	6	43	6	43	It's not clear what you mean by "demand management" here ... do you mean demand response/load shifting? The term "demand management" here also creates confusion since in the preceding sentence you say DSM programs are well-established.	Thanks. Well spotted. Will consider alternative language		Northwestern University	United States of America
57091	6	44	6	45	Another example is the difficulty ensuring a clean recycled glass or paper stream in the U.S. Mixed use recycling, while making it easy for consumers to recycle, creates a contaminated stream for glass and paper.	Waste management systems now mentioned		U.S. Department of State	United States of America
57091	6	44	6	45	Another example is the difficulty ensuring a clean recycled glass or paper stream in the U.S. Mixed use recycling, while making it easy for consumers to recycle, creates a contaminated stream for glass and paper.	Thanks good point but probably difficult to include too much detail here. Also, we could consider waste handling in developing countries.		U.S. Department of State	United States of America
70407	7	1	7	8	This is rather vague and could be made more concrete. It would be good to give account of some type of a roadmap that industry could assist in becoming carbon neutral, without claiming that this is "the only" roadmap. The text at the end of page 84 would be beneficial here to take part of this. In particular I miss a reference to the importance of carbon pricing in the Summary.	Carbon pricing is now mentione		European Union (EU) - DG Research & Innovation	Belgium
70407	7	1	7	8	This is rather vague and could be made more concrete. It would be good to give account of some type of a roadmap that industry could assist in becoming carbon neutral, without claiming that this is "the only" roadmap. The text at the end of page 84 would be beneficial here to take part of this. In particular I miss a reference to the importance of carbon pricing in the Summary.	Good point. Policy implications will be strengthened, include carbon pricing, etc		European Union (EU) - DG Research & Innovation	Belgium
85065	7	1	7	2	The statement that industry has been sheltered from the impacts of climate policy needs more nuance. In economies with ambitious carbon pricing policies, such as the EU or Australia in 2012-14, free permit allocation to address competitiveness concerns has been on an output-based updating allocation basis that preserves marginal abatement incentives while sharply reducing out-of-pocket costs to Emissions Intensive Trade Exposed activities. Another important point is that the traded nature of many key emissions intensive industrial products, combined with the unevenness of climate policies across countries, has largely sheltered consumers from price impacts of climate policy on these products. The sentence could be improved as follows: "Industry has so far largely been sheltered from net costs from climate policy due to concerns for competitiveness and carbon leakage; and consumers of emissions intensive industrial products have largely been sheltered from climate policy costs by the traded nature of these goods and the unevenness of climate policies across the world."	Partly ccepted. Para is revised: We do not take the suggestion on impact on consumers since it would conflict with statements and our asseessment that fossil free industry would have very little impact on cosumers		Australian Industry Group	Australia
23273	7	2	7	9	We recomand to mention the role of carbon pricing in the summary	Accepted.		Ministère de la Transition écologique et	France

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
23273	7	2	7	9	We recomand to mention the role of carbon pricing in the summary	See above. Same comment		Ministère de la Transition écologique et	France
23273	7	2	7	8	Mention the role of carbon pricing in the summary	Yes, ES will be revised with more information on policy	Ministère de l'Économie, des Finances	France	
57093	8	3	8	3	Suggested re-write: "The Paris Agreement (PA) and the 17 Sustainable Development Goals (SDGs) were adopted in 2015, a year after publication of AR5."	Rejected. Not clear what this adds		U.S. Department of State	United States of America
57095	8	5	8	6	Has there been any data on the impact of industry energy use from COVID? There have been big changes on transport energy use and some changes on buildings, though the industry part seems not to have changed much. What is the implication of that? People can stop traveling, work from home, but continue to consume industrial products? No change in consumption pattern?	The COVID impact is reflected later in the chapter, but the impact was not that large as for transport.		U.S. Department of State	United States of America
57097	8	5			The word "stimulus" may be incorrect, since some of these responses were relief, recovery payments offsetting lost economic activity due to disruption. The proliferation of global disasters such as fires and storms also contributed to the mind-shift.	Rejected. There were many suppoting economic policies to recover the economy. The substitute for stimulus was not suggested		U.S. Department of State	United States of America
82701	8	7	8	7	perhaps define here that "energy and emissions intensive industries" are referred to as "heavy industries" moving forward and stick with the latter term for consistency?	Thanks, we will ensure concistency		Northwestern University	United States of America
57099	8	12	8	13	Suggested edit: "… to limit global average temperature increase to 1.5 or 2°C above pre-industrial levels by 2100 ...".	Rejected. It is quite clear and text will be overloaded in such technical clarifications		U.S. Department of State	United States of America
57101	8	14	8	15	This sentence is poorly written and seems to mix up conventional definitions of direct and indirect emissions: "The industrial sector GHG emissions include direct and indirect fuel combustion related emissions, emissions from industrial processes and some products use, as well as from waste." It would be clear to say some thing like this: "Industrial sector GHG emissions include direct (scope 1) emissions from on-side fuel combustion and certain industrial processes, and indirect emissions (scope 2) associated with off-site electricity generation, purchased steam, or heat."	Thanks, we will edite everything for clarity and language		U.S. Department of State	United States of America
10801	8	15	8	17	This sentence is puzzling. Should one understand that this chapter will leave aside 40% of industrial emissions ?	We also discuss lighter manufacturing		CNRS	France
57103	8	15	8	16	This chapter is focused on "60% of of direct and total direct and indirect combustion and processes related industrial emissions (waste excluded)." Do authors want to make any comment about the other 40% to explain to the reader why no focus on these emissions?	Accepted. Clarifications are added		U.S. Department of State	United States of America
70409	8	15	8	15	The chapter delineates itself to emission intensive basic materials that would result in 60% of direct and indirect emissions. Perhaps it would be better to name the sectors and to check this 60% figure. In the EU ETS, refineries, basic chemicals, iron and steel and cement&lime account already for 75% of direct emissions and if you would add non-ferro, oil and gas extraction and building materials to this, you would end up over 85%. But perhaps you do exclude refineries and oil and gas extraction here and focus only on primary chemicals, minerals and metals. So define better what you want to say with "industry" and then check the 60% figure if it is still appropriate.	Accepted. Data were checked. The confusion often comes from comparison of shares in GHG and CO2 only emissions		European Union (EU) - DG Research & Innovation	Belgium
82703	8	15	8	17	here it would be important to better justify why there is not more focus on the other 40% of industrial emissions in the so-called "light industries," which must also be decarbonized and which may prove more difficult in some respects since they are comprised of many different production practices at may more smaller plants. giving the reader a clear and early view of a well-justified scope seems very important; currently, no early explanation is given	Accepted. Clarifications are added		Northwestern University	United States of America
57105	8	16	8	17	Currently the report says: ""This chapter is focused on the energy and emissions intensive basic materials industries that account for 60% of direct and total direct and indirect combustion and processes related industrial emissions (waste excluded)."" If Chapter 11 is going to focus primarily on the emissions from the five biggest material industries that account for most industrial GHG emissions, then this point needs to be called out more by: - Specifically highlighting which sectors these are - Including a graphic (e.g., pie chart) showing how they comprise most of the industrial GHG emissions - Highlighting the fact that these sectors are all very thermal energy intensive, many with high temperature process requirements - Highlighting that several of these sectors have process related emissions.	Accepted. Clarifications are added. This introductory part is only for very brief chapter introduction with details left fort the remainder chapter.		U.S. Department of State	United States of America
57105	8	16	8	17	Currently the report says: ""This chapter is focused on the energy and emissions intensive basic materials industries that account for 60% of direct and total direct and indirect combustion and processes related industrial emissions (waste excluded)."" If Chapter 11 is going to focus primarily on the emissions from the five biggest material industries that account for most industrial GHG emissions, then this point needs to be called out more by: - Specifically highlighting which sectors these are - Including a graphic (e.g., pie chart) showing how they comprise most of the industrial GHG emissions - Highlighting the fact that these sectors are all very thermal energy intensive, many with high temperature process requirements - Highlighting that several of these sectors have process related emissions.	Accepted. Clarifications are added. This introductory part is only for very brief chapter introduction with details left fort the remainder chapter.		U.S. Department of State	United States of America
60479	8	18	8	23	Here CCU is considered as an independant option, but in fact, it CCU combines the actions cited in the first sentences of this paragraph. Indeed, CCU contributes to 1) energy and material efficiency in storing and transporting energy via the power-to x approach, to 2) the deployment of renewable energy in storing and transporting electricity.3) create renewable feedstock for the production of alternative fuels, chemicals and materials and it supports circular economy (Bruhn et al., 2016, Arning et al, 2019, SAM, 2018,, SAPEA 2019, Hepburn et al., 2019, Wich et al., 2020), References: e.g. •Styring et al., 2011, Carbon Capture and Utilization in the Green Economy. Centre for Low Carbon Futures, York.,•Ampelli et al., 2015, Phil.Trans.R.Soc.A, 373., •GCI, 2016: Global Roadmap Study of CO2U Technologies, LUX Research & Global CO2 Initiative., ,•Bushuyev et al., 2018, Joule, 2(5), pp.825-832. •SAPEA, 2018, Science Advice for Policy by EU Academies, Novel Carbon Capture and Utilisation Technologies-Research and Climate Aspects, Evidence Review Report, 2. •Hepburn et al., 2019, Nature, 575, 87-97. Breyer et al., 2019, •Kätelhön et al., 2019, PNAS, 116, 23, 11187-11194. •CCES, 2019: Carbon Utilization – A vital and effective pathway for decarbonization, Center for Climate and Energy Solutions.. •Arning et al. 2019, Energy Policy, 125, 235–249.•Bruhn et al., 2016, Environmental Science & Policy, 60, 38–43. •Cuéllar-Franca and Azapagic, 2015, J.CO2.Utili., 9, 82-102..SAM, 2018: Novel carbon capture and utilisation technologies, Scientific Advice Mechanism (SAM), Independent scientific advice for policy making.•Wich et al. 2020, Frontiers Energy Research, 7, 162.	See above		Université Libre de Bruxelles / CO2 Value Europe	Belgium
83723	8	18	8	23	Here CCU is considered as an independant option, but in fact, it CCU combines the actions cited in the first sentences of this paragraph. Indeed, CCU contributes to 1) energy and material efficiency in storing and transporting energy via the power-to x approach, to 2) the deployment of renewable energy in storing and transporting electricity.3) create renewable feedstock for the production of alternative fuels, chemicals and materials and it supports circular economy (Bruhn et al., 2016, Arning et al, 2019, SAM, 2018,, SAPEA 2019, Hepburn et al., 2019, Wich et al., 2020), References: e.g. •Styring et al., 2011, Carbon Capture and Utilization in the Green Economy. Centre for Low Carbon Futures, York.,•Ampelli et al., 2015, Phil.Trans.R.Soc.A, 373., •GCI, 2016: Global Roadmap Study of CO2U Technologies, LUX Research & Global CO2 Initiative., ,•Bushuyev et al., 2018, Joule, 2(5), pp.825-832. •SAPEA, 2018, Science Advice for Policy by EU Academies, Novel Carbon Capture and Utilisation Technologies-Research and Climate Aspects, Evidence Review Report, 2. •Hepburn et al., 2019, Nature, 575, 87-97. Breyer et al., 2019, •Kätelhön et al., 2019, PNAS, 116, 23, 11187-11194. •CCES, 2019: Carbon Utilization – A vital and effective pathway for decarbonization, Center for Climate and Energy Solutions.. •Arning et al. 2019, Energy Policy, 125, 235–249.•Bruhn et al., 2016, Environmental Science & Policy, 60, 38–43. •Cuéllar-Franca and Azapagic, 2015, J.CO2.Utili., 9, 82-102..SAM, 2018: Novel carbon capture and utilisation technologies, Scientific Advice Mechanism (SAM), Independent scientific advice for policy making.•Wich et al. 2020, Frontiers Energy Research, 7, 162.	Thank you. CCU is extensively treated later in the chapter, i.e., 11.3.6		LUT University	Finland
47259	8	23	8	23	Explain why zero emissions is considered the backdrop of this chapter over net zero, and whether this implies CO2 or GHG. Also note that many of these basic material industries also cleverly use ' scope 3 compensation' as an offset to claim ' net zero' .	This is only an introductory part, which doesn't provides details for subsectors transition to the net zero		PBL Netherlands Environmental Assessme	Netherlands
57107	8	26			Provide a footnote that describes what the "The Kaya-identity" modeling tool is. Even if the Kaya-identity model was discussed in earlier chapters, or has been widely used in IPCC reports, don't assume all readers will be familiar with the approach. The report and chapter needs to be understood by wide varieties of readers.	Rejected. This is dealt with in chapter 2 and some other chapters which comes before the chapter 11. This is well known concept while IPCC reports are not textbooks.		U.S. Department of State	United States of America
15845	8	31	8	32	definition of material should be provided. It seems the meaning for material in material flow is different from that of material in material stock.	Rejected. Material stock is built from produced materials		KIET(KOREA INSTITUTE FOR INDUSTRIAL ECONOMICS & TRADE)	Republic of Korea
76477	8	32			tons are a unit of mass, not weight. Newton is the SI unit of weight. The imperial unit of weight is lb.	Accepted		Norwegian University of Science and Tech	Norway
15851	8	33	9	9	It is confusing the terminology among material efficiency, material intensity, material stock efficiency	Rejected. Those are well established terms explained in this section and formally presented in the equation 11.1		KIET(KOREA INSTITUTE FOR INDUSTRIAL ECONOMICS & TRADE)	Republic of Korea
57109	9	4	9	7	Define the terms. What do Mstock, MPR, MSE, GHGed, GHGeind, etc., mean?	Accepted		U.S. Department of State	United States of America
27831	9	5	9	6	The components of Equation 11.1 to be included in the table presented below the equation.	Accepted		Organization of the Petroleum Exporting C	Austria
57111	9	5	9	9	This equation is very important for the rest of the chapter, yet also very confusing. Given its importance, recommend taking a little more space here to help the reader interpret it. Start with a simplified version, condensed to say four total terms that are immediately intuitive. Explain that. Then expand your terms out to include the details like primary vs secondary materials, direct vs indirect emissions, material stocks vs material flows, process emissions, etc. Then put the terms next to the definitions in the table. Don't make the readers figure it out for themselves. Then, throughout the rest of the chapter, whenever authors refer to these drivers -- especially with Figures 11.1 and 11.2, and Section 11.3 -- use the exact same notation as in this equation. This framework is really powerful, but right now authors are counting on the reader to do an enormous amount of interpretive work in applying it, and that just makes it confusing. For example, on line 20 of the same page, authors refer to "the last three multipliers," but which ones? A little more discipline with notation would go a long way.	Some suggestions for more clarity are accepted. But there is no space to go from simple version of the equation to the one presented.		U.S. Department of State	United States of America
57111	9	5	9	9	This equation is very important for the rest of the chapter, yet also very confusing. Given its importance, recommend taking a little more space here to help the reader interpret it. Start with a simplified version, condensed to say four total terms that are immediately intuitive. Explain that. Then expand your terms out to include the details like primary vs secondary materials, direct vs indirect emissions, material stocks vs material flows, process emissions, etc. Then put the terms next to the definitions in the table. Don't make the readers figure it out for themselves. Then, throughout the rest of the chapter, whenever authors refer to these drivers -- especially with Figures 11.1 and 11.2, and Section 11.3 -- use the exact same notation as in this equation. This framework is really powerful, but right now authors are counting on the reader to do an enormous amount of interpretive work in applying it, and that just makes it confusing. For example, on line 20 of the same page, authors refer to "the last three multipliers," but which ones? A little more discipline with notation would go a long way.	Some suggestions for more clarity are accepted. But there is no space to go from simple version of the equation to the one presented.		U.S. Department of State	United States of America
2247	9	6	9	6	In equation 11-1, the definition of material is not clear, Dm should be also defined. Material stock cannot be measured explicitly. In my opinion, DM is not necessary in Kaya equation.	Thank you. This will be clarified		Hongik University	Republic of Korea
15847	9	6	9	6	It seems the meaning of this identity is necessary	Not clear what the comment says		KIET(KOREA INSTITUTE FOR INDUSTRIAL ECONOMICS & TRADE)	Republic of Korea
16547	9	6	9	6	In equation 11-1, the definition of material is not clear, Dm should be also defined. Material stock cannot be measured explicitly. In my opinion, DM is not necessary in Kaya equation.	Accepted. Material stock as it is shown in the chapter is measured in tons. Dm becomes important when mechanisms like CBAM or consumption based emissions are in focus		Korea Meteorological Administration (KMA)	Republic of Korea
52551	9	6	9	6	The decomposition put forth by Equation 11.1 is materials-centric; however, the authors should explain how energy intensity is embedded within that equation. It helps the reader link the discussion about the energy intensity data on page 16 to Equation 11.1 and Figure 11.2. Like, E/(MPR+MSE)*(MPR+MSE)/MStock*MStock/GDP=E/GDP.	It is clearly separated via E/((MPR+MSE)) parameter.		Sustainability Advisor to the Minister Ministry of Petroleum and Mineral	Saudi Arabia
57115	9	6			Equation 11.1 needs to explain what each variable represents (despite that some are explained here and there throughout the chapter).	Accepted		U.S. Department of State	United States of America
76479	9	6			Please provide a definition of the terms of the equation. Consider whether such a complex equation is required here.	Accepted		Norwegian University of Science and Tech	Norway
57113	9	6	9	6	It would be easier for the readers if the terms of the equations are horizontally listed and explained.	Accepted		U.S. Department of State	United States of America
70411	9	6	9	6	This equation is useful to frame the discussion, but please consider explaining all the terms immediately below the equation.	Accepted		European Union (EU) - DG Research &amp	Belgium
74899	9	6	9	6	Should define the factors/parametres of eaquation 11.1	Accepted		Kenya Meteorological Service	Kenya

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
82705	9	6	9	9	Blue and green table below the equation: I understand the aim to vertically align the columns with the terms of the identity, but I found it difficult to read since the vertical alignment is not perfect. I'd suggest just using a horizontal table and putting the variable names in a first column (rather than burying them in factor descriptions) for improved clarity. reading from right to left and looking up at the identity seems much easier.	Accepted		Northwestern University	United States of America
57121	9	7		8	Could the text be oriented horizontally?	Accepted		U.S. Department of State	United States of America
57123	9	7		8	Should there be a title for the blue box in the middle on the last row?	Accepted		U.S. Department of State	United States of America
57125	9	7		8	The connection of the table and the equation and body text is not clear. Why is this table here?	Accepted		U.S. Department of State	United States of America
2245	9	7	9	8	The table is not numbered and should be rotated to clockwise	Accepted		Hongik University	Republic of Korea
16545	9	7	9	8	The table is not numbered and should be rotated to clockwise	Accepted		Korea Meteorological Administration (KM	Republic of Korea
57117	9	7	9	8	is E emission or energy? Or should the reader read the reference to understand what each parameter means?	Clarified		U.S. Department of State	United States of America
15849	9	7	9	9	table is not readable and should rotate. Also the definition for the Dm variable is missing.	Accepted		KIET(KOREA INSTITUTE FOR INDUSTRIAL E	Republic of Korea
57119	9	7	9	9	Confused by the policies listed in this table. Are these just illustrative examples? What do authors mean by "population control policies"? This is really vague and hard to connect to industry. Think about whether including these "policies" add value to this table. Just the factors could be more helpful and less confusing.	Substituted with geographic policies. Population here is placed as traditional Kaya identity factor showing growing demand for services. There are multiple demographic policies		U.S. Department of State	United States of America
57127	9	11	9	11	This equation is difficult to follow and and to read the way it is positioned in the text. Can authors make this easier to read? Also it is hard to see where each factor or strategy comes in and how each has an impact in sequence with the others.	Accepted		U.S. Department of State	United States of America
15853	9	20	9	21	what are the three multipliers?	Put in parentheses (see below)		KIET(KOREA INSTITUTE FOR INDUSTRIAL ECONOMICS & TRADE)	Republic of Korea
57129	9	20	9	20	"last three multipliers": Add these multipliers in parentheses so the reader doesn't have to spend so much time on the equation.	Accepted		U.S. Department of State	United States of America
70413	9	20	9	20	These are not multipliers but ratios. Multipliers are in economics terms that describe how much GHG emissions would change in the end (in logarithmic models) if one of the underlying factors would change. However, equation (11) is entirely linear so the word multiplier is confusing here.	Rejected. There are math multipliers		European Union (EU) - DG Research & Innovation	Belgium
57131	9	23	9	23	Change "Energy efficiency dominate in the short- and medium-term and potentially long-term (in the range of 10-40% by 2050)" to "Energy efficiency is a key mitigation option throughout, with its impact dominating in the short- and medium-term and potentially long-term (in the range of 10-40% by 2050)."	Rejected. Literature doesn't agree with the proposed statement		U.S. Department of State	United States of America
85067	9	23	9	23	"dominate" should read "dominates"	Accepted		Australian Industry Group	Australia
47261	9	27	9	27	CAMBUREAU -> CEMBUREAU ?	Accepted		PBL Netherlands Environmental Assessme	Netherlands
57133	10	1	10	2	In Figure 11.1, the colors in the table and the diagram do not match, making readers confused about what the colors in the table represent.	Accepted	Government of United States of America	U.S. Department of State	United States of America
85069	10	1	10	2	The upper half of Figure 11.1 is very confusing and needs to be reconsidered. The vertical axis title needs to specify what is changing. Why are base year emissions (if that is what they are) above 100% of the base year level? Why do total emissions increase before declining? Why does the contribution of emissions free electricity and heat decline?	The figure is titled as stylized. As direct emissions are in chapter focus it was given 100% for the base year which is conditional and illustrative only. The evolution in time is stylized just to illustrate the composition of potential factors contribution. Nevertheless, the scale of relative contribution is based on literature studied and presented later in the chapter.	Suyi Kim	Australian Industry Group	Australia
57135	10	1	10	4	Should the y-axis label be change in GHG emissions relative to the base year? Why does the grey band for emissions free electricity and heat start so high and then disappear mid-way through the long-term phase? Make the colors of the bands in the graphic the same as the colors in the table. For example, in the graphic fuel switching and electrification of high temperature heat is dark orange, but in the table it is dark green. These should all be aligned.	Colors were made to match	Government of Republic of Korea	U.S. Department of State	United States of America
57137	10	1	10	4	It would be easier for readers if the y-axis of the top figure is labeled better. Does it mean "change in total CO2 emissions relative to the base year"? Which year is the base year? For the bottom figure, is the first column for "short-term mitigation options" and the second column for "medium/long term mitigation options"?	Accepted	Government of United States of America	U.S. Department of State	United States of America
82707	10	1	10	5	can you think of ways to more directly link the wedges to the terms of the kaya identity? Perhaps in the table below also list the relevant terms in the identity associated with each wedge? In the text, this relationship is described, but the visual linkage is lacking, potentially diminishing the importance of the kaya identity	This is already done in explaining equation 11.1 parameters and drivers. As related table was rotated it is easier now to see ho they match.	Government of United States of America	Northwestern University	United States of America
57139	10	2	10	2	Need titles for the two columns.	Accepted	Government of United States of America	U.S. Department of State	United States of America
57141	10	3			Regarding CCS and CCU, if concerned that oil-and-gas wells leak methane into the atmosphere, would there not also be concern that those same oil-and-gas wells used for CO2 storage would also be susceptible to leakage?	This is only conceptual figure, which doesn't go in requested details, which are subject of energy chapter	Yuan Yao	U.S. Department of State	United States of America
57143	10	6			To set the stage, authors should provide industry sectors share of emissions here at the start of this chapter. Something like (with an accompanying graphic): "Industry represents XX% of global emissions. Emissions from industry can be identified as AA% from Steel, BB% from Cement, CC% from Aluminum, DD% from Petrochemicals, EE% from Pulp-and-Paper, FF% Plastics, GG% from Pharmaceuticals and Specialty Chemicals, HH% Fertilizer." An inset graph could show the major categories of global emissions (Industry, Transportation, and Buildings).	This information is given in Ex summary and later in the section 11.2.	Edgar Hertwich	U.S. Department of State	United States of America
7703	10	8	11		noting to influence of technologies applied in industries, on rate of CO2 issue, suggestion is study and rating if factors influence on CO2 issue.	Rating is provided later in the chapter. This is only section which set the chapter conceptual stage	Shigetaka Seki	Meteorological	Iran
85071	10	8	10	9	For editorial and inclusiveness reasons, change "the mankind has been" to "humanity has been"	Accepted	Government of United States of America	Australian Industry Group	Australia
57145	10	8	10	9	Suggested re-write: "For centuries, humans have been producing ..."	Accepted	Government of United States of America	U.S. Department of State	United States of America
57147	11	1			The drivers in this paragraph should be in a list or table format.	Rejected. Suggested text restructuring doesn't make it better	Philippe Tulkens	U.S. Department of State	United States of America
9023	11	11	11	11	noting to influence of technologies applied in industries, on rate of CO2 issue, suggestion is study and rating if factors influence on CO2 issue.	This is done later in the chapter	Philippe Tulkens	IRIMO	Iran
10803	11	15	11	18	This is a very optimistic quotation; actually, (IRP,2020) says: "reducing demand by up to 20% (....) could lower GHG emissions from the material-cycle of construction materials in residential buildings by up to 73% in 2050 in the G7". Moreover, this "up to 73%" statement receives very weak justification if any.	Accepted	Tennant Reed	CNRS	France
82709	11	19	11	19	"smaller materials use" do you mean "less materials use?"	Accepted	Government of United States of America	Northwestern University	United States of America
43925	11	19			This "smaller material" does not sound right, I think "raw materials" would be more appropriate for define the material efficiency related to the supply chain and manufacturing of a final prodcut. The word "supply chain" also has broad and narrow definitions, I would suggest addressing this as "...focuses on supply chains and manufacturing considering ME..."	Accepted	Government of Norway	Yale University	United States of America
57149	11	20	11	22	Is it because other new drivers offset the contribution from these policies? Give an example.	Rejected. This section does not discuss policies and there have been few/no ME policies	Eric Masanet	U.S. Department of State	United States of America
74901	11	22	11	22	Figure refered to should be Fig. 11.2 not 11.1	Rejected. Reference is correct	Government of United States of America	Kenya Meteorological Service	Kenya
72827	11	22	11	22	The statement "expected to change in the future" is particularly interesting and useful. But it should be developed a little because is it short or long term, is it consensual ? The figure 11.1 shows the many parameters involved but does it prove it? Maybe elaborate with one or several examples of this foreseen trend	Rejected. Elaboration is provided later in the chapter. The introductory section should not provide all details	Government of United States of America	EE-Consultant	France
57153	12	1			Authors state that process emissions are increasing (page 4, line 32), so why are the GHG-others bars all negative? Also, this is another great opportunity to use the exact same notation as in Equation 1, performing a little more interpretive work for the reader.	There is no contradiction as ratios of combustion related emissions to material volumes are declining faster comparing with ratios for process related emissions thus reflecting the growing share of process related emissions	Government of United States of America	U.S. Department of State	United States of America
76481	12	1			It is not clear why the role of emissions-free electricity and heat decreases and disappears. If it already contributes to decarbonization in the base year, its presumable contribution will only grow.	In case the figure 11.1 due to decarburization of power and heat indirect emissions becomes zero. This is considered as external to industry factor originating in energy sector.	Government of United States of America	Norwegian University of Science and Tech	Norway
2249	12	1	12	1	In Figure 11.2, 10th column from the left is empty. The next of GHG emissions (other)/materials is blank.	The separation box is added to split the figure by 2 sections	Tennant Reed	Hongik University	Republic of Korea
16549	12	1	12	1	In Figure 11.2, 10th column from the left is empty. The next of GHG emissions (other)/materials is blank.	See above	Government of United States of America	Korea Meteorological Administration (KM	Republic of Korea
57151	12	1	12	1	Figure 11.2 needs a bit more explanation. For example, the driver of secondary materials/material stock increases since 2000 and is quite high for the period 2014-2018, but there is no discussion in the text of what this is and why the growth was so high. Also, all of the categories of GHG emissions get confusing: GHG emissions (direct energy)/energy GHG emissions (indirect energy)/energy GHG emissions (other)/materials GHG emissions total (direct and indirect) GHG emissions direct GHG emissions (direct energy) GHG emissions (indirect energy) GHG emissions (other)	Ratios used are directly related to the equation 11.1. Some explanations are provided at thee text, but limited chapter space doesn't allow to get in more details here. Clarification is added - Factors correspond directly of equation 11.1.	Government of United States of America	U.S. Department of State	United States of America
82711	12	1	12	1	can you put the identity variables (e.g., Mstock/GDP) in the series labels for the drivers in Fig 11.2? A small change like this would help readers more easily map back to the kaya identity	Rejected. In case variables will used instead of their names we may expect the request to use names. So, in the figure caption the comment was added on the correspondence with equation 11.1	Government of United States of America	Northwestern University	United States of America
2251	12	13	12	13	How to measure material stock?	In tones. There is discussion in this section showing this.	Government of United States of America	Hongik University	Republic of Korea
16551	12	13	12	13	How to measure material stock?	See above	Eric Masanet	Korea Meteorological Administration	Republic of Korea
57155	12	26	12	27	Authors suggest that this material growth is strongly coupled with GDP growth (which it is), but isn't the story also about increased urbanization and consumerism?	The suggested discussion is the subject for the chapter 5	Government of United States of America	U.S. Department of State	United States of America
27833	12	1	12	1	Figure 11.2 to present data without having overlapping years for the last two periods (i.e. no overlap for 2010-2018 and 2014-2018).	That is done to show how trends after AR% differ from whole after 2010 decade trends	Philippe Waldteufel	Organization of the Petroleum Exporting C	Austria
72829	12	1	12	1	Figure 11.2 is interesting but could gain (i) with a reference to the kaya equation used from equation 11.1 (2) explain in the notice the proposal that material efficiency is improving emissions at a later stage as stated p.11 l22.	Accepted	Government of United States of America	EE-Consultant	France
57157	13	1	13	23	Is it possible that some of the slowness in material stock may be coming from deferred maintenance of infrastructure that is just deferring material requirements?	This is explained in the text following the figure	Government of Germany	U.S. Department of State	United States of America

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
57159	13	1	15	38	Stocks vs. flows of materials seems co-mingled in this passage. Energy is always a flow, so this made the relationship between material numbers and energy numbers especially hard to interpret. The stock vs. flow issue also made it hard to interpret the relationship between Figure 11.3 and the text. And the insets in Figure 11.3 are not sufficiently explained. The stocks v. flows issue comes up again on page 18.	There is literature (covered in the chapter) showing the difference between material stock and material us evolution at different stages of economic development	Government of United States of America	U.S. Department of State	United States of America
15855	13	9	13	9	(Krausmann et al. 2018)	Unclear comment	Tennant Reed	KIET(KOREA INSTITUTE FOR INDUSTRIAL E	Republic of Korea
85073	13	15	13	16	Remove errant "," from "even fast, than GDP per capita". The sentence ends with an open bracket and appears to be missing a reference and full stop.	Accepted	Government of United States of America	Australian Industry Group	Australia
57161	13	16	13	16	Sentence appears to be missing a citation.	It sends to the figure where sources are listed	Government of United States of America	U.S. Department of State	United States of America
82713	13	18	13	23	this sentence was hard to follow; reword for clarity?	Accepted	Government of United States of America	Northwestern University	United States of America
82715	14	1	14	1	this graph is rich with great information but it is also pretty busy, and should probably be simplified. Notably the second inset with the regression is hard to read and it's not clear why the regression equations are relevant since they are not discussed in the text	Visibility will be improved and comment of regressions is added.	Eric Masanet	Northwestern University	United States of America
57163	14	1	14	7	In Figure 11.3, why are grazed biomass and fodder crops, wild catch and harvest, crops, crop residues included here in the industry chapter? Also, why are fuels (oil shale and tar sands, petroleum, natural gas, coal, wood) included here? This chapter does not include the GHG emissions associated with extraction of these commodities and production of crops, etc.	Rejected. Biomass and fuels in some parts are used as feedstock in industry.	Government of United States of America	U.S. Department of State	United States of America
57165	14	2			Wild Catch and Harvest are indistinguishable color differences on the graph.	Accepted	Government of United States of America	U.S. Department of State	United States of America
57167	14	2			Wild Catch and Harvest are indistinguishable color differences on the graph from Crops.	Accepted	Eric Masanet	U.S. Department of State	United States of America
27835	14		14		Figure 11.3 to present more recent data for raw natural materials extraction, if available.	The latest data available are presented	Government of United States of America	Organization of the Petroleum Exporting C	Austria
10805	15	8	15	12	Is this way of counting the share of the energy sector compatible with estimates based on LCA? Which is best ?	The relevance of this comment to the text referred is not clear	Damien Lamy	CNRS	France
76483	15	11	15	17	Somewhat odd exposition. Please use more natural language. I think it is commonly accepted that recycled materials can replace virgin materials, so please try to say this shorter and more to the point.	Accepted	Government of United States of America	Norwegian University of Science and Tech	Norway
15857	15	12	15	12	down-cycling?	It is term in use by the literature	Government of United States of America	KIET(KOREA INSTITUTE FOR INDUSTRIAL E	Republic of Korea
43923	15	12			Here upcycling is not mentioned, chemical recycling processes are able to turn plastics into diffierent building block chemicals that can be used to produe higher value-added products (which industry would be more interestd given the economic attrativeness). I suggest including "upcycling" after "downcycling" in this sentence.	Here we speak about past tends where upcyclig was very limited	Edgar Hertwich	Yale University	United States of America
57169	15	13	15	13	The text in footnote 7 should be in the paragraph and not in a footnote.	Rejected. Here discussion is on recycling rates not specifically on environmental benefits of recycling, which are dealt with later in the chapter.	Government of United States of America	U.S. Department of State	United States of America
76485	15	13			Footnote 7 claims that the environmental impacts of secondary materials is an order of magnitude lower than that of primary materials. That is not generally true. Table 6 in Cooper and Gutowski (http://doi.wiley.com/10.1111/jiec.12388) provides numbers and indicates that there are at best minor savings for cement and plastic and smaller savings that you suggest for steel and paper. Further, we cannot assume that marginal energy and emissions savings from increased recycling will be the same as average. In fact, a paper in final revisions at ES&T shows that a further increase in Cu recycling in the US would yield lower marginal emissions savings that current recycling due to the lower quality of remaining scrap. I am happy to provide more detail if desired.	Accepted. Softer statement is made. But here discussion is on materials, not on products life extension.	Government of United States of America	Norwegian University of Science and Technology	Norway
70415	15	16	15	16	"the liner metabolism", this probably should be "the linear metabolism"	Thanks, will be corrected	Government of United States of America	European Union (EU) - DG Research &amp	Belgium
85075	15	16	15	16	Reference to "the liner metabolism" may be a typo - is "the linear metabolism" intended?	Accepted	Edgar Hertwich	Australian Industry Group	Australia
57171	15	18	15	22	What does "old scrap ratio" mean? What does "for another ten" mean? Also, these data are too old for AR6. Report on data from around 2014 to present.	Thanks. Changed to (end of life) scrap. Means another ten metals. New references added	Changke WANG	U.S. Department of State	United States of America
64173	15	18	15	26	There is good technical reason why recycling rats for metals are higher than other metals. Plastics are diverse to meet speicific requirements of specific use and plastics contributes much in saving energy as insulators, light waight materials for vehicles and various types of containers, anti-corruptive packages, and so on. Materials are diverse and additives add another dimension of diversitiy. Much energy and resource are needed to recycle plastics in general except for pipes and window frames. In many case, thermal recovery is the most energy efficient and low emmiting solution. Simple comparizon between different materials are thus misleading. In addition, discussion should be made on degradation in the process of recycling. Even in the best performance case of aluminum, only 70 percent of aluminum cans can be recycled into material for cans and the rest can be used at best as dicasts. This means that replacement of virgin material has technological limitation in any material.	Thank you. The discussion on recycling details is later in the chapter. Here only historical trends are dealt with.	Government of United States of America	Consumer Product Safety Association	Japan
70417	15	22	15	24	I see here two indicators: share of scrap-based production and share of old scrap. Not clear what the difference is between them. Perhaps it would be useful if either one of these indicators was chosen	Referred text is quite clear on which indictor is used	Damien Lamy	European Union (EU) - DG Research & Innovation	Belgium
70419	15	27	15	33	What is missing here is the fact that carbon pricing in extractive and refining industries is still very partial, as can be observed from the OECD publication on Effective Carbon Rates (https://www.oecd.org/ctp/effective-carbon-rates-2018-9789264305304-en.htm). The limited carbon price tends to be passed onto consumers, contrary to what is being said here. Actually, the available academic evidence shows that even compensation mechanisms exists to reduce carbon leakage, sectors in the EU ETS have still been passing through the opportunity costs of carbon allowances in the product prices (see e.g. Cludius et al., 2020, DOI: 10.1016/j.eneco.2020.104883.	The commented text says this	Changke WANG	European Union (EU) - DG Research & Innovation	Belgium
85077	15	30	15	30	Correct "industrial lobbing" to "industrial lobbying"	Thanks	Government of China	Australian Industry Group	Australia
85079	15	31	15	35	Strongly disagree with the statement that carbon policy compensation mechanisms cause upstream sectors to fail to pass carbon costs downstream. In fact this is precisely backwards: compensation policies exist because of the inability of trade-exposed upstream industries to persuade customers to accept price rises for costs not borne by trade competitors. However the lack of downstream price signals is important for the reasons subsequently elaborated. This could be a point to introduce the distinction between carbon policy approaches that compensate for the inability to pass on costs, and carbon policy approaches like border adjustments that enable costs to be passed on.	Rejected. AS it is shown in the chapter low carbon materials costs much more that undermine the competiveness of those producing them, while associated increments in final products prices mostly stay within 1% range.	Government of United States of America	Australian Industry Group	Australia
29769	15	35	15	38	Please consider deleting or rephrasing the sentence; " [..] falsely designated as `hard to abate` [..]". Much of the rest of the chapter describes in detail the considerable technological and institutional challenges involved in decarbonising the production of basic materials, and so does the sited source, Material Economics, 2019. `Hard to abate` is not defined here, so any judgement on whether this sector can be described as such seems difficult without some further elaboration.	Accepted	Edgar Hertwich	Norwegian Environment Agency	Norway
57173	15	35	15	38	Does this mean the authors think that industry is not hard-to-abate, and its CO2 emissions can be easily reduced/eliminated? Does this mean that through material efficiency, and if material efficiency is 100% implemented, industry will be easy to abate? No primary steel or new cement will ever need to be produced, globally?	Accepted	Tennant Reed	U.S. Department of State	United States of America
82717	15	35	16	4	the message from the preceding paragraphs is that materials intensity keeps rising and this is a problem, but it is never stated explicitly what should be the societal targets for materials intensities in a low-carbon world with decent living standards for all. it would be great for the reader to have this context here. could these "more sustainable" and perhaps asymptotic levels of materials/GDP be extracted from some of the cited scenario studies showing large acheivalbe reductions in materials (e.g., IRP, Grubler et al. LEDS, material economics) to at least give the reader a ballpark of what levels we need to aim for?	This section deal with historical trends. The following sections do discuss the potential contribution of ME to mitigation.	Government of United States of America	Northwestern University	United States of America
57175	15	36			The text identifies industrial greenhouse gas emissions as "falsely" thought to be hard to abate. Most would think that they are actually hard to abate.	Accepted	Government of United States of America	U.S. Department of State	United States of America
57177	15	36			This may be one of the reasons, but there are many others, such as unclear consumer benefits or incentives, lack of knowledge and information from end users, high temperature heat processes has limited options for alternative fuels, etc. There is only one reference provided for this point, so this point should be qualified or more references added.	Text clearly says "is part of the reason".	Government of United States of America	U.S. Department of State	United States of America
57179	15	37	15	37	The term "hard-to-abate" mostly implies sectors that need high temperatures that are difficult to produce without fossil fuels. How is material efficiency related to this?	There different reasons for labeling hard to abate, and problems with ME and materials substitution are among them.	Philippe Tulkens	U.S. Department of State	United States of America
57181	16	5	16	6	Suggested re-write: "From 2014-20XX, global industrial energy use average annual growth rate (AAGR) was limited to 0.7% compared to 2.8% in 2000-2014 …" Provide the range of years for this growth rate 2014 ????.	Accepted	Haris Doukas	U.S. Department of State	United States of America
57183	16	5	16	18	Add a table here to provide these values since they are so important for this chapter and not clearly presented (with definitions) in this paragraph. Non-energy use needs to be defined.	There is no space for extra table	Government of United States of America	U.S. Department of State	United States of America
70421	16	9	16	10	Direct energy use....accounts for 30% of final energy consumption. Not clear what is being meant here. Final energy consumption of industry? (then I would find the number very low), Or final energy consumption globally?	Accepted. Clarification is added	Nikas Alexandros	European Union (EU) - DG Research &amp	Belgium
82719	16	10	16	11	perhaps remind the reader here that "non energy use" = "feedstocks," which is the term used earlier	Done by just a few lines below	Takeshi Kuramochi	Northwestern University	United States of America
57185	16	12	16	13	Doesn't the primary energy use take into consideration the indirect use in electricity and heat and other energy conversion and extraction already? Why does it need to have two different figures?	Both metrics are shown in the text with one includes indirect energy use.	Government of Kenya	U.S. Department of State	United States of America
82721	16	14	16	16	perhaps avoid the use of dashes before the percentages (e.g., "-51% on average") since these may at first glance be interpreted as negative values	Accepted	Philippe Waldteufel	Northwestern University	United States of America
52553	16	19	16	23	There is an issue with the time periods in this sentence, "...industrial energy intensity (per value added using market exchange rates) globally dropped by 16% in 2010-2018 after its 6% growth in 2000-2010, resulting in 2010-2018 decline by only 10.5%." It reads like that last time period should be 2000-2018.	Thanks	Eric Masanet	Sustainability Advisor to the Minister Mini	Saudi Arabia
57187	16	19	16	21	Regarding these sentences: ""For over a century industrial energy efficiency sustainably mitigates GHG emissions (Figure 11.2). In 2010-2018, global aggregated industrial energy efficiency indicators were progressing slower, than in 1971-2000."" 1) Which indicator(s) in Figure 11.2 represent energy efficiency? This is not clear here or in the description of the figure. 2) Why do authors only discuss 2010-2018 and 1971-2000? What about 2000-2010? 3) The syntax needs improvement in these sentences.	Along provided comments this section was rewritten	Antoine BONDUELLE	U.S. Department of State	United States of America
57189	16	19	16	29	Why would energy efficiency slow overall but accelerate per ton of material? How does that work? How much of these changes are driven by structural shifts in the industrial sector as opposed to changes in performance within existing industrial activities?	Along provided comments this section was rewritten	Government of United States of America	U.S. Department of State	United States of America
57191	16	21	16	21	What does "they" refer to here?	Along provided comments this section was rewritten	Stefanie Kunkel	U.S. Department of State	United States of America
70423	16	21	16	23	"industrial energy intensity [...] dropped by 16% in 2010-2018 after its 6% growth in 2000-2010, resulting in 2010-2018 decline by only 10.5%" Please check whether the last part is correct and should not be "resulting in 2000-2018 decline by only 10.5%"	Along provided comments this section was rewritten	Philippe Tulkens	European Union (EU) - DG Research &amp	Belgium
57193	16	23	16	23	Suggest revision to: "The 2020 COVID-19 ..."	Thanks	Richard Bohan	U.S. Department of State	United States of America
85081	16	23	16	25	"COVID crisis slowed down energy intensity improvements by shifting industrial output towards more energy intensive basic materials" should instead begin "Infrastructure-oriented economic stimulus responses to the COVID crisis…"	Rejected. Message is different	Government of United States of America	Australian Industry Group	Australia
57195	16	30	16	39	Do not forget energy efficiency. It will continue to serve an important role as well.	It already talks about BAT which is mainly EE	Philippe Tulkens	U.S. Department of State	United States of America

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
57197	16	31	16	31	"were" should be "was"	Rejected. There three indicators listed	Tennant Reed	U.S. Department of State	United States of America
82723	16	39	16	39	in this context "fundamental process changes" means fuel switching via advanced processes, so perhaps it should be termed as such?	Rejected. There are much more than fuels switch as discussed in the chapter	Yuan Yao	Northwestern University	United States of America
57199	17	3	17	4	This is a key finding that is missing from the Executive Summary: "Material efficiency coupled with energy efficiency can deliver much greater savings than energy efficiency alone." This does not imply however that energy efficiency cannot deliver important GHG reductions.	Accepted.	Tennant Reed	U.S. Department of State	United States of America
82725	17	3	17	5	It seems as if something should be said here on the tension between material efficiency and scrap availabilty for recycling; one goal of ME is longer stock lifespans, meaning less scrap availability each year for new production, which may limit ability to reduce SECs via more recycling. IEA ETP 2017 discusses this, for example. There will be some optimum balance, of course, but discussing the interdependence seems important here since the reader may conclude that ME and recycling are mutually exclusive savings when they are not.	Rejected. Not that simple. Material efficiency also means designing products for circulation after EOL or EOU.	Government of United States of America	Northwestern University	United States of America
57201	17	6	17	6	Define exergy (or provide a hyperlink). Also, it seems to be a big concept for materials efficiency and the circular economy, yet is used only four times in this chapter.	Rejected. This is textbook term	Government of United States of America	U.S. Department of State	United States of America
17215	17	12	17	12	Another addition to this useful section would be a brief comparison of emissions estimates for the industry sector. Are there futher datasets to compare against the main sources described here (EDGAR, IEA)? Perhaps for specific subsectors or regions? One could also compare earlier years against AR5. This would be an important quality check on the results shown here and elsewhere. For info, Ch7 (AFOLU) does this for Agricultural and LULUCF emissions (see section 7.2.1).	Accepted	JAE YOON LEE	Mercator Research Institute on Global Co	Germany
17211	17	12	17	32	This is a nice, but short section. The presented results focus mainly on the global trends, overlooking the large regional differences highlighted in Figure 11.5. It is perhaps interesting to note, for example, the predominance of Eastern Asia in the last two decades of growth, the shifting industrial structure of North America and Europe (less Metals and Chemicals, more Other), and the importance of the waste sector in developing regions. Overall, it would be great to dig deeper into the data and answer the question - what are the most substantive and rapid sources of global industry emissions growth?	Rejected. There is limits room for this section as there is chapter length limit. The figure 11.5 was designed to make quite visible the contribution of different regions to GHG growth. The same vertical scale was applied.	Government of Kenya	Mercator Research Institute on Global Co	Germany
57203	17	12	17	12	Shouldn't this be: "New trends in GHG emissions …"	Accepted	Government of United States of America	U.S. Department of State	United States of America
82733	17	12	17	12	it would be good to add at least some brief discussion of waste emissions, wastewater emissions, and emissions from CH4, N2O, and F-gases in this section. Those emissions sources appear prominently in the figures in this section but are never explained (what are their key sources, etc.)	Thank you. Will consider this	Government of United States of America	Northwestern University	United States of America
70425	17	13	17	21	This paragraph is not very clear. Are these nubmers including or excluding feedstocks? Furthermore: "Overall industrial GHG emission amounts to 13.4 Gt for direct emissions (with 10 GtCO2 contribution, Figure 11.4c)" It is not clear where the 10 GtCO2 contribution in parentheses refers to.	Figures 10.4 presents data for CO2. Clarification is added.	Tennant Reed	European Union (EU) - DG Research &amp	Belgium
57205	17	13	17	17	Authors use different units throughout these four lines of text. They should be standardized. Same comment for the associated footnote 15.	CO2-eq is used for CO2 equivalent, while for CO2 only CO2 is used. To escape repetition of units in some cases one GT are shown.	Eric Masanet	U.S. Department of State	United States of America
82727	17	15	17	15	can you give an example of emissions from product use (0.2 Gt) for the reader? Though these emissions are small, some readers may think this refers to operational emissions of manufactured products instead of what it really refers to (oxidation of lubricants, etc.)	Chapter 2 gives details. We do not comment here on other items. As to example - it includes solvents in paint and N2O used for anesthesia	Government of Saudi Arabia	Northwestern University	United States of America
46745	17	18	17	18	The reference Stephenson et al. (2018) is missing	Not clear comment	Eric Masanet	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety International Climate Policy	Germany
57207	17	19	17	20	It is unclear what "the corresponding shares" refers to. Clarify.	Accepted	Government of Kenya	U.S. Department of State	United States of America
57209	17	22	17	23	This was mostly driven by growth in China, or China plus a few other key countries. If that is true, add this information so that the reader doesn't think industrial emissions have grown evenly around the world.	11.2.3 discusses this	Constantinos Psomopoulos	U.S. Department of State	United States of America
57211	17	27	17	28	This observation on electrification is an important one that perhaps warrants noting in the Executive Summary and other places in this chapter.	Accepted	Yuan Yao	U.S. Department of State	United States of America
57213	17	28	17	30	This was mostly driven by growth in China, or China plus a few other countries. If that is true, add this information.	11.2.3 discusses this	Government of United States of America	U.S. Department of State	United States of America
85083	17	28	17	30	This sentence would be clearer if it added nonjudgmental references to emerging economies: "This quiet evolution was interrupted in the beginning of the 21st century, when surging industrial output in several emerging economies, notably China, saw world direct industrial emissions increase by 52-72% depending on the metric applied (the fastest growth ever seen)."	11.2.3 discusses this	Government of Kenya	Australian Industry Group	Australia
3681	17	32	17	32	structure -> structured	Accepted	Government of United States of America	Mines Saint-Etienne	France
74915	17	35	17	36	Delete the hard start to make the sentence continuous	Accepted	Government of United States of America	Kenya Meteorological Service	Kenya
57219	17	36			Errant ")." to start line.	Accepted	Government of United States of America	U.S. Department of State	United States of America
3683	17	36	17	36	extra parenthesis	Accepted	Eric Masanet	Mines Saint-Etienne	France
49765	17	36	17	36	to remove extra parenthesis	Accepted	Government of United States of America	CSIR-CIMFR, Dhanbad	India
85085	17	36	17	36	Line begins with errant close bracket and full stop, possibly missing from end of line 35 or else from a deleted piece of text.	Accepted	Government of United States of America	Australian Industry Group	Australia
57215	17	36	17	38	The statement here sounds as if the solutions are those listed when in reality there are other options that the chapter discusses later. Qualify the statement.	Rejected. This only comments on the importance of IPPU	Shigetaka Seki	U.S. Department of State	United States of America
57217	17	36	17	38	This conclusion may be misleading. Although it may be the case for those countries that have gone through industrialization to focus on secondary processes, those that are still developing and going through industrialization still require significant effort to reduce emissions from primary production. Thus the pathway is not one-way straight, but multiple and by different timelines.	Rejected. The statement says 'more' not exclusive	Changke WANG	U.S. Department of State	United States of America
82729	17	36	17	38	not sure this sentence is needed; the points have been made before and this statement is so high-level that it doesn't add much; if it is retained then one would need to explain why "product use" emissions should be a priority (since they are very small) and what is meant by "waste decarbonization" (this is the first mention and no explanation is given)	Rejected. This statement doesn't speak about priority. it just stressed importance of IPPPU which is often overlooked in many studies.	Changke WANG	Northwestern University	United States of America
85085	17	36	17	36	Line begins with errant close bracket and full stop, possibly missing from end of line 35 or else from a deleted piece of text.	Accepted	Government of United States of America	Australian Industry Group	Australia
76487	18	1	18	4	Thanks for acknowledging my work, at least partially. The cited numbers are actually based on a paper that existed only in pre-print form at the time the other pieces were written. It has now appeared in Nature Geoscience: https://doi.org/10.1038/s41561-021-00690-8. We now do have data up to 2018 and could calculate changes also on a per kg basis.	Accepted. This paper was cited	Government of United States of America	Norwegian University of Science and Technology	Norway
57221	18	4	18	6	What is "their present carbon footprint"?	Accepted. Clarification is added	Government of United States of America	U.S. Department of State	United States of America
70427	18	7	18	10	The statement in the text "GHG emissions per unit of energy showed steady decline" is referenced to the Figure 11.2. However, from the figure no such development can be observed as the figure presents absolute GHG emissions and shares.	Rejected. Figure 11.2 presents rates of change for which negative numbers mean reductions.	Cécile Seguineaud	European Union (EU) - DG Research &amp	Belgium
3685	18	10			you only talk about sand and agregates 2 times	Unclear	Philippe Tulkens	Mines Saint-Etienne	France
57223	18	11	18	11	Don't understand the right-hand scale (emissions structure) in Figure 11.4a. What does the 80% at the top represent? 80% of what? So in 2018, industrial emissions were ~75% of what? Can't be total GHG emissions. Clarify.	Accepted. Clarification is provided.	Tennant Reed	U.S. Department of State	United States of America
82731	18	11	18	11	this figure needs a number; also, it would be very good to define what is included in the use (i.e. PU) component of IPPU, since the graph lumps process and product use emissions together by sector. I understand the PU to refer to oxidation of in-use chemicals, etc., which you stated in earlier paragraphs is fairly small (0.2 Gt). Not sure what the PU could be for cement, since technically use-phase emissions are negative due to carbonation, so perhaps that label should just be IP? So, some clarity is needed for interpreting the labels.	Accepted. Clarification is provided.	Government of United States of America	Northwestern University	United States of America
57225	18	11	19	8	For Figure 11.4a, the lines superimposed on the area plot are confusing, so likely better to use an inset. For Figure 11.4b,c,d, why aren't the totals for the direct emissions in these three subplots equal? Figure 11.5 is mostly unreadable. Also, the line colors should match the lines showing the same quantities in Figure 11.4a.	Numbers are checked and clarifications ate added	Government of United States of America	U.S. Department of State	United States of America
57227	18	12	18	12	In footnote 17, for what year are the IRP (2020) values presented? Also, again a problem with all of the different (and sometimes incorrect) units/labels, with some outright missing.	Accepted. Clarification is provided.	Government of United States of America	U.S. Department of State	United States of America
57229	18	12	18	12	Footnote 18 nearly repeats information provided in footnote 17.	Accepted. Coordinated and repetition is removed	Tennant Reed	U.S. Department of State	United States of America
30565	19	0	20	0	It is better to show CO2 emissions instead of GHG emissions, as this figure shows various indicators for CO2 emissions.	Reject. The figure shows GHG emissions	Hiroyuki Tezuka	Climate Change Division - Ministry of Fore	Japan
57231	19	1	19	1	Use different colors in Figure 11.4b and Figure 11.4c -- that is, don't use the same blue, orange, grey, yellow colors to represent different things in graphs that are next to each other. Also, can the y-axis scales of Figure 11.4b,c be the same (i.e., both go to 20 GtCO2eq)?	Accepted. Recolored	Damien Lamy	U.S. Department of State	United States of America
57233	19	1	19	1	Suggested revision to Figure 11.4b label: "(b) Total 2018 industrial GHG emissions by major sources". Standardize how decimal points are presented throughout the document. Map these values to the last column of Table 11.1. For example, in the Figure 11.4b, industrial combustion is shown as 6.79 GtCO2eq whereas in the table it is 6.711. The values for indirect emissions and waste look correct, but industrial processes and product use values in the table add to 3.320 GtCO2eq which is not what is reflected in the graphic. Then there is the remaining 1.857 GtCO2eq for non-CO2 GHG. This seems to have been added into the industrial process and product use category. Is this correct or should it be its own category?	Some corrections were made. Compared data in the table are on CO2 only	Government of United States of America	U.S. Department of State	United States of America
57235	19	1	19	1	The 2018 direct emissions in Table 11.1 are 6.711 GtCO2eq. What is being plotted in Figure 11.4c? It is all industrial GHG emissions except indirect emissions from electricity and heat? If so, then the figure label should state this more clearly. Standardize how decimal points are presented throughout the document.	Some corrections were made. Compared data in the table are on CO2 only	Government of United States of America	U.S. Department of State	United States of America
57237	19	1	19	1	The figure title says 1970-2018, which seems to only be applied to Figure 11.4a. Improve the title for Figure 11.4a by adding this and remove it from the overall Figure 11.4 title.	Accepted	Government of United States of America	U.S. Department of State	United States of America
57239	19	1	19	1	The label for Figure 11.4d says direct emissions only, but authors likely mean all GHG emissions except indirect emissions from electricity and heat. Improve the label.	Accepted	Government of United States of America	U.S. Department of State	United States of America
15859	19	4	19	4	the graphs in Figure 11.5.(a) are not readable.	Accepted	Rebecca Dell	KIET(KOREA INSTITUTE FOR INDUSTRIAL E	Republic of Korea
57241	19	4	19	7	Remove the 1990-2018 from the Figure 11.5 title and add it to Figure 11.5a only. Standardize how decimal points are presented throughout the document. Delete "Indirect emissions were assessed using (IEA, 2020b)."	Accepted	Rebecca Dell	U.S. Department of State	United States of America
82735	19	4	19	5	lots of great information in this graph but the individual region insets are so small that they are very hard to read; is there another way to present the information? Perhaps put the cumulative sector contributions into the waterfall chart for each region and delete the individual region insets?	Rejected. This style is used in chapter 2 on trends. Final figure designer will make it readable	Rebecca Dell	Northwestern University	United States of America
17213	19	5	19	5	Interesting and useful figure. I wonder if it would make sense to simplify this somewhat. In particular, perhaps the shares of basic materials + shares of IPPU (which I think also needs further explanation in the text or caption) could be in a single dedicated figure, along with the global trend (from figure 11.4a). The trends seem to diverge substantially by region, but I am not sure what is being communicated by this. It is also not desirable to overlay two separate axes on the same figure, as it invites confusion and misinterpretation from readers.	The chapter space limitation doesn't allow to haw more figures for this section	Government of United States of America	Mercator Research Institute on Global Co	Germany
27837	19		19		Figure 11.5, section (a), the vertical axes for the different regions to be clearly indicated.	Accepted	Government of United States of America	Organization of the Petroleum Exporting C	Austria

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
57243	20	1			Maybe shade the boxes according to the size of the change? A lot of those numbers have too many significant figures.	Rejected. We need consistent coloring across sectors and regions	Government of United States of America	U.S. Department of State	United States of America
57249	20	2			Illustrate combined emissions by sector including direct, indirect, and process related. This way readers will see more clearly which sector is the big emitter.	Rejected. Combined emissions are depicted	Eric Masanet	U.S. Department of State	United States of America
57245	20	2	20	2	Suggested revised title: "Table 11.1: Dynamics and structure of global industrial GHG emissions, 1970-2018." Standardize how decimal points are presented throughout the document.	Will be possible upon data availability	Government of United States of America	U.S. Department of State	United States of America
57247	20	2	20	3	Other non-CO2 GHG is growing fast and the share is nearly doubling between 1970 and 2018. Some more elaboration would be helpful in a separate table. Looking at SF6 would be extremely helpful, given its potency and its use in electrical equipment.	Rejected. This section length limit doesn't allow to go deeply in the emissions structure by each gas	Government of United States of America	U.S. Department of State	United States of America
82737	20	2	20	3	it would be helpful to improve the alignment of categories in Table 11.1 with the series presented in the figure on page 18, line 11. for example, table 11.1 has one row for "waste" but the figure contains series for landfills/incineration and wastewater (do these two series sum to the "waste" total?). if the rows in the table could be more easily related to the series shown in the graphs (i.e., through the use of common labels) that would help.	Rejected. This table was developed not to replicate the figures, but to show separately widely discussed and presented CO2 emissions	Government of United States of America	Northwestern University	United States of America
27839	20		20		Table 11.1, the average annual growth rates to be presented in the third period over the years 2001-2010, to allow consistency with the previous periods.	Not clear suggestion. 2000-2010 is already there	Government of United States of America	Organization of the Petroleum Exporting C	Austria
57251	21	1	21	1	Suggested change: "The significant increase in industrial emissions after 2000 is clearly ..."	Rejected. Present text is preferred	Government of Norway	U.S. Department of State	United States of America
63097	21	2	21	4	China does not separate from other Asian countries in Figure 11.5. Please change "China's and other non-OECD Asian countries" into "non-OECD Asian countries".	Rejected. There are references to this statement from the literature are added	Mariel Vilella	National Climate Center, China Meteorological Administration	China
76489	21	2	21	35	Here you say that there will be a saturation at specific stock level. It smacks of determinism. Further, it contradicts earlier statements. In section 11.2.1, you argue for material efficiency, and that development can rely on less materials. In Fig. 11.2 insert, the materials stock seems to be increasing at least linearily with GDP per capitca, which would suggest there is not saturation. Of course, saturation can be in some materials, whereas others grow more than porportional. Still, the overall line of argument needs to be considered.	Rejected. Text speak only about saturation at some income levels. IEA in NZE relay on stock saturation in developed countries	Government of United States of America	Norwegian University of Science and Technology	Norway
57253	21	26	21	29	This reference has China's industrial sector CO2 emissions peaking before 2019: Zhou, N., Lu, H., Khanna, N., Liu, X., Fridley, D., Price, L., Shen, B., Feng, W., Lin, J., Szum, C., Ding, C., 2020. China Energy Outlook: Understanding China's Energy and Emissions Trends. Berkeley, CA: Lawrence Berkeley National Laboratory.	Thanks	Government of United States of America	U.S. Department of State	United States of America
3687	21	30			you talk a lot about steel and cement throughout the paper, however from the best of my knowledge, buildings also require sand and stones/gravels for concrete making (as you mention). what about numbers concerning these materials, and the impact of their usage/extraction ?	There is some discussion on those materials. They are plotted at figure 11.3, but they are not carbon intensive.	Government of United States of America	Mines Saint-Etienne	France
63099	21	33	21	35	India's demand for steel over the next 30 years is not comparable to China's current steel production. In addition, The expression is lack of data or literature support. It is suggested to delete "- and that still only represents two-thirds of China's current steel production."	Rejected. References are there	Suyi Kim	National Climate Center, China Meteorological Administration	China
15281	21	36	21	42	Lines 38-40 discuss the consumption-based emissions. It can be seen that lines 40-41 conclude that "Carbon emissions embodied in international trade are estimated to account for 20-30% of global carbon emissions". However, carbon emissions embodied in international trade are not carbon leakage and there is conceptual confusion in this connection. This paragraph discusses industrial development and supply chains, and there is no evidence indicating that changes in trade flows are due to climate policies, or related to carbon leakage. It is suggested to delete the sentence "Tracking consumption-based emissions allows it to detect "carbon leakage" and provides additional insights in the global effectiveness of national climate policies."	Accepted and corrected	Government of Republic of Korea	China Meteorological Administration	China
57255	21	36	22	17	On international trade, authors should highlight that about a quarter of world GHG is traded across borders. Consider this recent peer-reviewed report by GEI, The Carbon Loophole in Climate Policy- Quantifying the Embodied Carbon in Traded Products: https://www.globalefficiencyintel.com/carbon-loophole-in-climate-policy The report uses the most recent available data and a cutting-edge model to conduct a global assessment of the extent of the embodied carbon in globally traded goods. GEI also published a report in 2021 on Embodied Carbon In the U.S. Manufacturing and Trade: https://www.globalefficiencyintel.com/report-embodied-carbon-in-the-us-manufacturing-and-trade	Rejected. Suggested references relay on OECD estimates which are already reflected in the text.	Government of United States of America	U.S. Department of State	United States of America
76491	21	36	22	17	What is the intension of this section? Would you like to discuss industrial supply chains and their role in emissions, or the general issue of consumption vs. production based emissions and weak carbon leakage? Your literature review is not up-to-date. At a different place, you cite my recent emissions-in-supply-chains analysis. There is other work on the general consumption-based accounting, see e.g. https://doi.org/10.1080/14693062.2019.1619507	References are updated. This section set the stage for former CBAM discussion	Government of United States of America	Norwegian University of Science and Technology	Norway
85087	21	36	22	17	It is worth noting here that there does not seem to be any causative relationship between implemented OECD climate policies and the shift in emissions intensive production to non-OECD economies. Anti-leakage elements of policies like the EU ETS seem to have been effective to date, within their limited scope of operation (which is to avoid causing leakage, not to prevent international economic integration). Trends in outsourcing of production have been similar in economies with different levels of climate policy ambition and reflect broader policy and economic drivers.	Accepted. The section is rewritten	Government of United States of America	Australian Industry Group	Australia
57257	21	38	21	39	Suggested re-write: "Tracking consumption-based GHG emissions allows detection of 'carbon leakage' and provides additional insights on the global ..." Authors could substitute "consumption-based CO2 emissions" if that is more accurate.	Accepted. The section is rewritten	Cédric PHILIBERT	U.S. Department of State	United States of America
57259	21	40	21	41	When authors say "carbon emissions" (2x in this sentence), do they mean CO2 emissions?	Fixed	Cédric PHILIBERT	U.S. Department of State	United States of America
57261	22	12	22	13	Suggested re-write: "It should be noted that exports from countries with lower product emissions lead to overall lower emissions ..."	Fixed	Philippe Tulkens	U.S. Department of State	United States of America
70429	22	12	22	17	The statement in this sentence is not correct in it's present form. However, if you would replace "lower product emissions" in the sentence by "lower emissions per unit of product" and "high emission countries" by "countries with higher emissions per unit of product", the statement becomes correct.	Accepted	Yuan Yao	European Union (EU) - DG Research & Innovation	Belgium
3689	22	15			this should be put in perspective as renewable production facilities require also cement/concrete/steel and require to be set in fields thus implying artificialisation of soils. studies should be conducted on a systemic approach.	Rejected. This Para is just on reallocation of business.	Government of United States of America	Mines Saint-Etienne	France
60191	22	19	22	19	While my earlier comment on the FOD was rebutted, I still think that 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. This is, in my view, an important point of departure for any discussions on long-term options for deep decarbonisation. A few references that can be added (all of which were not part of the Fifth Assessment Report) here: 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 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	The inssues of energy efficiency and CO2 reduction in steel are considered in section 11.3.4.	Government of United States of America	NewClimate Institute	Germany
74903	22	19	39	36	Technology develpoment and options .In order to decarbonize the industrial sector, there is need to consider and address the technology gaps in the developing coutries.This ranges from acquisition,adoption and commercialization	Technological development for developing counties is addressed in sections: 11.2.3 Industrial development patterns and supply chains (regional); 11.5.2 Current industrial and broader policy context.	Stefanie Kunkel	Kenya Meteorological Service	Kenya
10807	22	20	22	23	while Interdependency is not a major problem, overlapping should be avoided as much as possible	Agreed. The overlaps and interactions are discussed more in section 11.3.7.	Eric Masanet	CNRS	France
49767	22	20	22	20	To consider sentence correction: "….. is organized in six partly 2 overlapping"	The text "partly overlapping, independent" has been removed, and a new setnence has been added for clairty: "Each strategy is described in detail, followed by a discussion of possible overlaps and interactions between strategies and how conflicts and synergies can be addressed through integration of the approaches."	Government of United States of America	CSIR-CIMFR, Dhanbad	India
57263	22	20	22	22	Unclear why there is a 2 at the end of line 20 and a 4 at the end of line 22.	Corrected	Government of United States of America	U.S. Department of State	United States of America
27841	22	20	22	23	Number 2 to be removed from the text in line 20, and number 4 from line 22.	Corrected	Government of United States of America	Organization of the Petroleum Exporting C	Austria
82771	22	20	22	23	here it would be good to mention that the overlaps and synergies between these strategies are discussed in section 11.3.7, since overlaps are mentioned here with no elaboration	See response to comment 49767	Government of United States of America	Northwestern University	United States of America
72831	22	20	22	23	This widening of the action on industrial emissions is broader than the previous equivalent chapters of IPCC reviews. Maybe mention this enlargement of policy possibilities it in the paragraph	We have changed the text to highlight this point "The following overview of technical developments and mitigation options which relate to the industrial sector"	Cédric PHILIBERT	EE-Consultant	France
82741	22	21	22	25	"demand management" is listed a distinct concept but section 11.3.1 doesn't really describe what is "demand management" and how it differs conceptually from ME; rather section 11.3.1 focuses almost exlusively on demand trends without discussing management; management is hinted at in the final few sentences but refers to Ch 5. so either the distinct management aspects should be discussed or demand management should be deleted as a distinct category?	"Demand management" has been change to "Demand for materials" to reflect that 11.3.1 section is describing the demand trends for materials, whereas 11.3.2 describes ME, which is a demand management strategy.	Philippe Tulkens	Northwestern University	United States of America
57265	22	25	25		This section did not clearly delineate the difference between demand management, material efficiency, and circular economy. Maybe using the terms from Equation 1 would help.	This section is intended to provide an overview of the stratgies. We acknowledge there are some overlaps between these approaches, and these are discussed in section 11.3.7. See also comment 82741	Eric Masanet	U.S. Department of State	United States of America
2253	23	1	23	1	Explain which materials are not included in Figure 11-6 and why they are not.	Reject: Fig 11.6 is intended to show that demand for selected key materials has grown rapidly (x3.5) over the last 20 years. The list includes materials where global data was readliy available. The grpah excludes all other materials, of which there could be thousands of different types, apart from cement, aluminium (primary), plastic (key thermoplastic resins), steel (crude) and glass. The material trends are normalised to 100 in 1990, to avoid giving absolute material demand figures, thus isolating the trend in growing demand. We expect many other materials to also follow this trend.	Philippe Tulkens	Hongik University	Republic of Korea
16553	23	1	23	1	Explain which materials are not included in Figure 11-6 and why they are not.	See response to comment 2253	Philippe Tulkens	Korea Meteorological Administration (KM	Republic of Korea
57267	23	1	23	1	Can Figure 11.6 be updated to 2018? It might be interesting to add the indexed population growth and urbanization to this chart.	Fig 11.6 includes data up to 2019 (caption corrected, and date axis changed). We have added the global population growth over this period.	Government of United States of America	U.S. Department of State	United States of America

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
82739	23	1	23	1	It might help to put the legend to the right and order the legend categories to correspond to the order of the final values from top to bottom	Order in legend changed, but caption position not changed. Will be re-formatted during the production phase of the report to be in line with IPCC visual guidance"	Suyi Kim	Northwestern University	United States of America
85089	23	20	23	22	Remove errant numeral 2 at the end of line 20 and errant numeral 4 at the end of line 22	Corrected.	Government of Republic of Korea	Australian Industry Group	Australia
70431	23	22	23	23	This statement that materials demand forecasts have been "adjusted" suggests that the saturation effect is something new. But this effect was already demonstrated by Malenbaum in 1978. (Malenbaum (1978). World Demand for Raw Materials in 1985 and 2000, McGraw-Hill, New York). So this was pretty much common knowledge after the Club of Rome report and material demand forecasts at Resources of the Future always took this into account. So it would be good to emphasize that such an effects was recorded long time ago in the scientific literature and included in materials demand forecasts since the late 1970s.	Correct. Saturation effects have been included in material dmeand forecasting in academic literature. However, this is often overlookedon industry planning, regulation and policy. We have changed "Recent modelling" to "Modelling" to avoid implying that saturation effects is a new idea. However, we have not incuded any older literature in the review.	Eric Masanet	European Union (EU) - DG Research & Innovation	Belgium
43955	23	24	23	27	I disagree with the statement that once saturation is attained, stocks can be maintained with much reduced demand for materials. This runs counter to the Downs-Thomas paradox where building more highways increases traffic congestion. There may be an equilibrium point where the building stock accurately reflects demand but it's incorrect to say that the building stock becomes saturated.	Reject. Life-cycle analyses of products (i.e. building, vehicles, roads,etc) show that less material is always to mainain a product, than to produce the product in the first place. For example, a typical car requires 1.5 tonne of steel to make, but only kilograms of steel across it's lifetime to maintain. Saturation of per capita material stocks in developed countries is an emperically observed trend at country level. It results in reduced material requirements.	Stefanie Kunkel	Portland Cement Association	United States of America
57269	23	24	23	29	Given that most of emissions growth will be in non-OECD countries, material efficiency strategies in OECD countries may have limited worldwide impact unless the circular economy can greatly reduce demand for primary materials.	Reject: Material efficiency stratigies, which reduce the amount of material required to delive a service, will be equally effective in both developing and developed economies. For developed countries ME might allow per capita stocks to reduce (i.e.e halving from ~16 t steel per person, to ~8 t sttel per person). For developing countries, ME allows reduction in material demand, by allowing service levels to be improved (towards develop country levels) with less material (i.e. from ~1 t steel per person, to ~8 t steel per person). However, we agree that material production will need to be increased to meet the development needs for the global south.	Government of United States of America	U.S. Department of State	United States of America
51307	23				It should be highlighted that few positive environmental effects of Industry 4.0 are proven in the literature (see also Beier et al. (2020): https://www.sciencedirect.com/science/article/pii/S0959652620309033) and rebound effects are likely. See comment below and comment 10 on chapter 16.	Industry 4.0 is covered in section 11.3.4.2 Smart energy management.	Government of United States of America	Institute for Advanced Sustainability Studies (IASS), Potsdam	Germany
70433	24	1	24	1	The notion of growing demand for certain materials required to transition to a carbon neutral economy stands at odds with the leveling off of material demand in mature economies, as discussed in the previous paragraphs. I suggest to stress that the total in use stock of materials in mature economies will grow and stabilize at a new, higher level compared to previous levels.	Agreed. Have expaded the sentence on new low-coarbon infrastrutre: :Furthermore, meeting climate change targets in developed countries will require the construction of new low-carbon infrastructures (i.e. renewable energy generation, new energy distribution and storage systems, electric vehicles and building heating systems) which may increase demand for meissions intensive materials (i.e. steel, concrete, glass)."	Government of Germany	European Union (EU) - DG Research & Innovation	Belgium
85091	24	1	24	4	Would be worth expanding on the point about new materials demand associated with decarbonisation - perhaps a cross reference if this is addressed elsewhere in WGIII. Expansion should involve noting some example needs (such as the steel, cement and glass required for large scale renewable energy generation); noting that the emissions associated with these materials typically do not outweigh the mitigation potential of these technologies; but noting that the material input needs to build a clean economy increase the importance of technologies to cleanly produce materials.	See comment 70433.	Rebecca Dell	Australian Industry Group	Australia
57271	24	3	24	3	Here it says that aluminum has shown little evidence of saturation. But on page 23, lines 16-23, it seems to say that aluminum has reached saturation. Both of these two places are discussing developed countries.	"Aluminium" has been removed from the list.	Yuan Yao	U.S. Department of State	United States of America
15861	24	5	24	8	decription should be more specific; any example of the method to maintain low per capita material stock level with economic development	We have added references to (Grubler et al. 2018) which addresses the issues of economic growht and attaining development in the global south, partly through reduction in demand for materials.	Government of United States of America	KIET(KOREA INSTITUTE FOR INDUSTRIAL ECONOMICS & TRADE)	Republic of Korea
43927	24	13	24	48	One strategy that seems to be missing in this entire material efficiency section is material substitution. In the building sector, there are many emerging wood products such as cross-laminted timber that have been commercialized and would provide singificant life-cycle GHG reduction benefits compared to traditional construction materials such as steel and concrete. Those biogenic materials store carbon while they are in use and they should be mentioned and highlighted. I suggest two references here for wood-based materials and buidings: (1) https://iopscience.iop.org/article/10.1088/1748-9326/abc5e6/meta (2) https://www.nature.com/articles/s41893-019-0462-4	The industry chapter focuses mainly on material efficiency in industrial facilities. Material substituion, as a strategy is dealt with in other chapters, such as Ch9 Building and Ch10 Transport. Material switching is however included in the overal demand projections for the industry chapter. (Note, we do not agree that timber offers significant emissions reduction, over steel and concrete buildings, when compared on a like-for-like delivery of a building structure. CLT timber, still includes signifcant amounts of steel (fixings) and concete (foundations), and construction timber current has emissions from drying the timber).	Antoine BONDUELLE	Yale University	United States of America
85093	24	23	24	24	Figure 11.7: Correct "intensiveley" to "intensively" in box marked "USE"	Thanks, corrected.	Government of United States of America	Australian Industry Group	Australia
57273	24	23	24	26	In Figure 11.7, for the box on manufacturing, should higher quality and/or better performance be included?	"Improve quality" added to manufacturing box.	Eric Masanet	U.S. Department of State	United States of America
20087	24	30	24	33	Gramkow and Anger-Kraavi (2019) also performed a modelling excercise based on E3ME for the manufacturing sector of Brazil including materials savings and recycling: -Gramkow, C., & Anger-Kraavi, A. (2019). Developing Green: A Case for the Brazilian Manufacturing Industry. Sustainability, 11(23), 6783.	Reject: the paper suggested makes no reference to material efficiency strategies, instead focusing on energy efficiency and decarbonisation.	Government of Canada	National Technical University of Athens, Greece	Greece
20155	24	31	24	32	See also (E3ME for Brazilian ME): Gramkow, C., & Anger-Kraavi, A. (2019). Developing Green: A Case for the Brazilian Manufacturing Industry. Sustainability, 11(23), 6783.	See comment 20087	Stefanie Kunkel	National Technical University of Athens	Greece
57275	25	1		11	Can authors give concrete examples for each of the industries, what specific measures or technologies can be deployed, and are they mature and commercial. What about costs? Rather than stating it exists, policymakers and readers could use the specific information to inform decisions. In addition, are there new emerging technologies such as 3D printing? It can reduce the waste material needed for cutting, etc.	Reject. Gneric ME stratgeies for the industry are shown in Fig 11.7 across the lifecycle stages. Given the numerous ME interventions possible, and their specitivity to each sector, we refer to examples in literature which discuss sector specific ME examples. Note, Additive Manufacturing has only limited ME benefit, mainly in metal parts where light-weighting is at a premium (i.e. aerospace). AM provides little ME gain for plastics, where mass-production of polymer products already has high manufacturing yields and low energy use, due to economies of scale which are not present for AM.	Government of United States of America	U.S. Department of State	United States of America
57277	25	12	25	12	Add either CO2 or GHG before "emissions" to be more precise.	Corrected. Added "GHG".	Government of Norway	U.S. Department of State	United States of America
74905	25	31	27	17	Most research into Industrial symbiosis focusses on industrial ecology or eco design principles which is largely prescriptive and technical neglecting the business analytical aspects which matter highly for innovation(Felicio, Amaral et al., 2016).	Reject: this comment relates to industrial symbiosis, which is consdiered in 11.3.3 Circular economy and industrial waste	Jasmin Kemper	Kenya Meteorological Service	Kenya
2361	25	42	25	47	In terms of more work, there is more work needed in policy development to encourage and incentivize more circular economy principles across the supply chain. Perhaps this is touched upon elsewhere in the chapter.	Reject: this comment relates to industrial symbiosis, which is consdiered in 11.3.3 Circular economy and industrial waste	Philippe Tulkens	Lawrence Berkeley Lab	United States of America
82743	25	42	25	46	it might be helpful here to specifically call out the fields/domains that the IAM community needs to better engage with for improved ME modeling, notably the LCA and Industrial Ecology communities, to make needed next steps more actionable	Sentence added: "Efforts should be prioritised to foster engagement between the Integrated Assessment Models (IAM) community and emerging ME models based in the Life Cycle Assessment, Resource Efficiency and Industrial Ecology communities."	Government of Canada	Northwestern University	United States of America
85095	25	42	25	47	Overall the ME discussion in 11.3.2 is excellent. In this closing paragraph it would be good to add two points: 1. bolster the reference to tradeoffs on materials and energy efficiency with some examples; for instance, extending the lifespan of vehicle stocks can slow the adoption of cleaner vehicles; and highly integrated products may be more energy efficient, but harder to repair or recycle, than more modular products. 2. Make a specific cross-reference to Chapter 3, to the effect that ME is not incorporated into (most? all?) of the integrated assessment models considered there (as per 3.4.4 page 49 lines 19-21)	Link to Chapter 3 added. Trade offs between material efficiency and energy efficiency are discussed in Section 11.3.7.	Philippe Tulkens	Australian Industry Group	Australia
47263	26	1	26	1	How is circular economy distinguished from material efficiency? (section uses substantial space to continue explaining on material efficiency (also covered in previous section).	CE covers much broader than material efficiency. ME is one core area of CE, but has a special role in industry since CE aims to improve the overall material efficiency in industry.	Mario Valentino Romeri	PBL Netherlands Environmental Assessme	Netherlands
70435	26	1	26	23	There is a certain inherent overlap between the sections of material efficiency and circular economy. For example, some of the strategies for material efficiency in Figure 11.7 are covered in section 11.3.3 on the circular economy, eg Renault's design for recovery. I suggest to clarify the difference between circular economy and material efficiency.	In this industry chapter, we specifically focus on CE's application in industry by saying that "From an industrial point of view, CE focuses on closing the loop for materials and energy flows by incorporating policies and strategies for more efficient energy, materials and water consumption, while emitting minimal waste to the environment". Thus, material efficiency is just one component of CE in this context. CE has a much broader implication.	Government of Germany	European Union (EU) - DG Research &amp	Belgium
57279	26	1	27	49	This whole section is quite weak. Probably the weakest part of the chapter.	This is one biased comment. To promote CE in industry is meaningful since significant GHG emission can be avoided through the implementation of CE in industry, such as industrial symbiosis, energy/water cascading, eco-design, etc.	Eric Masanet	U.S. Department of State	United States of America

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
43919	26	1	28	10	The GHG emissions of recycling, remanufacturing, remelting/reforming could be significant, the actual GHG emission mitigation of different CE approaches need careful examination from a life-cycle perspective (e.g., using Life Cycle Assessment) rather than assuming it is always carbon-beneficial. The recycling technologies and supply chains could be carbon-intensive and careful analysis, selection, and design of the recycling processes and relevant infrastructure should be considered when practicing CE approaches. The current section does not include such discussions, it could be misleading to indicate that as long as CE is used and virgin materials are avoided, then the entire supply chain and product are "green" or carbon beneficial.	Thank you for your useful comments. Yes, indeed some of recycling processes may be carbon emission intensive. But beyond carbon emission reduction, such recycling process can lead to much less consumption of virgin materials. Since the extraction and processing of virgin materials are typically energy-intensive, it is still deserved to encourage such recycling activities since co-benefits can be obtained. But you are right, a life cycle based assessment may be necessary to evaluate the overall benefits. We added such statements in the revised version, saying "However, careful evaluation is needed from a life cycle perspective since some recycling activities may be energy and emission intensive. "	Government of United States of America	Yale University	United States of America
52563	26	1			The Circular Carbon Economy (CCE) is a holistic, integrated, inclusive, and pragmatic approach that was acknowledged by G20 countries and has many literature talking about the CCE. The CCE framework includes a 4th R demonstrated in 'Remove' to compliment the 3Rs of Circular Economy. Such an approach should be within the recognized and mentioned approaches in the report	The 4R proposed by Saudia Arabia is specifically referred to carbon, not industry. In this chapter, we focus on CE in industry and therefore 3R is more appropriate. The "REMOVAL" of carbon is normally through CCUS, which is discussed later in this chapter.	Government of United States of America	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
57281	26	1	28	10	While the concept of CE is very appealing, there may need to be the creation of new legal or institutional structures to enable the full potential for these opportunities. For example, to achieve maximum reuse requires knowledge of the complex products' composition that may only be available to the original manufacturer, so a means of creating a database/knowledge infrastructure with more detail than simple recycling logo that allows for maximum material reuse. Also, remanufacturing/recycling infrastructure that is established by a single manufacturer can become orphaned if the firm goes away, so creating durable structures (e.g., a no-profit that recovers/recycles/remanufacturers solar panels) that would be able to persist beyond the life of any one company.	Yes, some of your points are very critical. We did several surveys and found that many practitioners expect to get more accurate information from other stakeholders for potential industrial symbiosis opportunities. But we also found that all the activities should be conducted through the commercial channels without any interventions. The famous kalundborg industrial symbiosis was created through such commercial cooperation and has been maintained for many years. We presume that this is the right approach to promote industrial symbiosis, rather than through governmental interventions. But we do agree with you that an information platform (such as a database) is cucial to facilitate CE and therefore added such a stataement in the end of this sub-section, saying that " Also, an information platform should be created at the national level so that all the stakeholders can share their CE technologies and expertise, information (such as materials/energy/water consumption data), and identify the potential synergy opportunities."	Government of United States of America	U.S. Department of State	United States of America
74907	26	1	26	43	Kenya has also made some significant progress in promoting the industrial park concept with the enactment of the Special Economic Zones Act(2015)	I presume that you are right, but I need more data, such as the benefits generated from eco-industrial park projects, not just mentioning that EIP is being implemented worldwide.	Eric Masanet	Kenya Meteorological Service	Kenya
74917	26	1	28	10	consider including examples from India, Africa and South America, in addition to other critical developing countries eg https://www.researchgate.net/publication/332416054_Accelerating_the_transition_to_a_circular_economy_in_Africa	There are many CE practices reported by different authors from different countries. I read your proposed literature, but did not find any specific contents that I can include in this sub-section as I expect to provide more quantitative information, rather than qualitative information.	Government of United States of America	Kenya Meteorological Service	Kenya
80389	26	1	27	29	Here it must be pointed out that in terms of circular economy and industrial wastes there are several types of industrial wastes that are transformed to alternative fuels for industrial processes, and thus their added value is high and supports the circularity in industrial sector. A good example are the multiple alternative fuels of cement industry derived from multiple waste sources (see publication e.g : Chatziaras, N., et al. (2016), "Use of waste derived fuels in cement industry: a review", Management of Environmental Quality, Vol. 27 No. 2, pp. 178-193. https://doi.org/10.1108/MEQ-01-2015-0012) This point is of paramount importance to achieve circularity in industrial wastes and it goes beyond the scrap approach, and thus should be included here in this point.	The point that you mentioned was already stated in the same industry chapter of AR5, in which it says:" The examples from Japan ((Hashimoto et al. 2010), Hidaka city (Morimoto et al. 2006)) have shown that CO2 emissions can be reduced to 15%-20% by use of municipal solid waste in cement kilns." Therefore, we tried not to repeat the same statement in this AR 6 report.	Rebecca Dell	University of West Attica, Department of Electrical and Electronics Engineering	Greece
82747	26	1	26	1	the authors acknowledge partial overlap between ME and CE concepts (page 22, line 22) but don't elaborate. it would be very helpful if they could also add some explicit discussion of how ME and CE overlap but still remain important distinct concepts for climate policy makers and analysts to consider. the literature often conflates ME and CE and/or uses the terms interchangeably, so there is an opportunity for this chapter to offer some clarity.	Thank you for your comments. We revised our statement in Line 16 of Page 26, saying "In particular, CE aims to improve the overall material efficiency in industry since material efficiency can deliver greater savings, than energy efficiency alone." We hope that such a statement can clarify the relation of CE and ME. Although it would be better to have more detailed description here, due to the words limitation, we can only use this sentence to clarify the relations of CE and ME.	Government of United States of America	Northwestern University	United States of America
63101	26	4	26	7	It is not appropriate to cite Geng et al. 2013 on the definition of circular economy. Please cite some papers of the authors who have contributed to the definition of circular economy. For example, Durning, A.T. How much is enough? The consumer society and the future of the earth.London: Earthscan Publications, 1992	There is no globally accepted CE definition. Different authors may use different definitions by considering different needs and contexts. This definition cited here is from a paper published in Science, one of the most significant academic journals in the world. It has explained the real meaning of CE in the industrial context. We do not think it inappropriate.	Rebecca Dell	National Climate Center, China Meteorological Administration	China
63103	26	4	26	29	In this paragraph, the relationship between circular economy and carbon reduction is not fully discussed. It is suggested to supplement some discussions and related literature.	You are right. We added one more sentence in Line 6 of Page 26, in which it reads: "In particular, since CE promotes reduction, reuse and recycling in all the industrial sectors, a large amount of virgin materials can be saved, leading to significant carbon emission reduction because the extraction and processing of virginal materials are always energy and emission intensive. "	Government of United States of America	National Climate Center, China Meteorological Administration	China
3691	26	9			same ref as Wiebe et al. ?	Yes.	Eric Masanet	Mines Saint-Etienne	France
70437	26	9	26	11	The statement that energy consumption in Primary Alumium can only be improved by 4% is correct, but there is a very substantial scope for improvement by making aluminium from renewable electricity. So this option should be mentioned here as well, as at the moment it makes a comparison only from the material efficiency economy but not from the climate perspective.	For Kana	Government of United States of America	European Union (EU) - DG Research & Innovation	Belgium
85097	26	9	26	11	The aluminium sentence is inelegant and could be clearer. Change line 9 "in case aluminium" to "in the case of alumiinium". What is "continuous switching"? Spell out both savings from BAT-level SECs and recycling in the same terms (percentage).	For Kana	Eric Masanet	Australian Industry Group	Australia
2363	26	11	26	14	This sentence is hard to understand. "Improved recycling rate allows for a substantial reduction in energy use along the whole production chain — material extraction, production, and assembling, — which is in great excess of energy spent for collection, separation, treatment, and scrap recycling minus energy needed for scrap landfilling."	For Kana	Government of United States of America	Lawrence Berkeley Lab	United States of America
85099	26	11	26	14	This statement about the net energy savings from recycling is good but needs clarification: is the point made with respect to materials generally; or ores and metals specifically?	For Kana	Cédric PHILIBERT	Australian Industry Group	Australia
57283	26	16	26	17	Why is this sentence in the section on circular economy and industrial waste when the section on material efficiency comes just before? Material efficiency can deliver greater savings than energy efficiency alone. Also, if included here or elsewhere, this sentence needs a reference.	For Kana	Rebecca Dell	U.S. Department of State	United States of America
57285	26	16	26	17	What savings does this refer to? Energy or in all cases? Also, it would be helpful to provide a reference to avoid making an assertive statement.	For Kana	Government of United States of America	U.S. Department of State	United States of America
57287	26	17	26	23	Not sure that this discussion belongs in the section on circular economy and industrial waste. Perhaps move this to the section on steel (11.4.1.1)?	For Kana	Max Wei	U.S. Department of State	United States of America
57289	26	24	26	24	It's not clear what "This systemic approach" is referring to. Clarify or modify the sentence.	Here we say that CE is a systemic approach. We revised as "As one systemic approach, CE has been conducted at different levels."	Alex Rau	U.S. Department of State	United States of America
82745	26	24	28	10	Ch 5 covers some of the same definitions and concepts related to CE, so there appears to be an important opportunity to coordinate with Ch 5 to reduce overlap and maximize synergies	Chapter 5 focuses on CE in general, while our chapter focuses on CE in the industrial context.	Antoine BONDUELLE	Northwestern University	United States of America
57291	26	29	26	29	Delete "The following paragraphs detail such efforts."	We deleted it.	Rebecca Dell	U.S. Department of State	United States of America
2365	26	30	26	31	Suggest rewriting "Increasing firms began to implement the concept of CE, particularly those multi-national 31 companies, since they believe that multiple benefits can be obtained from CE efforts" to "More firms have begun to implement the concept of CE, particularly those multi-national companies, since they believe that multiple benefits can be obtained from CE efforts."	We have revised this sentence accordingly. Thank you.	Philippe Tulkens	Lawrence Berkeley Lab	United States of America
57293	26	30	26	30	Suggested re-write: "Increasingly firms are beginning to implement the concept of CE, particularly multi-national ..."	See the above respone.	Government of United States of America	U.S. Department of State	United States of America
57295	26	30	26	42	This paragraph read like an advertisement for Dow Chemicals, which is both uninformative and inappropriate.	We do not have any personal relations with this Dow company. We cited this case due to its appropriateness, not due to any commercial purposes at all.	Jeffrey Merrifield	U.S. Department of State	United States of America
64175	26	30	26	42	Yes DOW is trying to replace all plastics with polyethylene advocating that it will become easier to recycle. However, it is not yet known if such approach is realy effective. To emulate diverse plastics, polyethylene needs to be designed differently for specific applications. This means that the polyethylene will be very diverse and the diversity is maintained when mixed with those for other applications and be melted for recycling. This is the distinctive difference from metals. It is dubious that mixture of diferent types of polyethylene can become material as high value as each type of polyethelene. The technical difference between metals and plastics needs to be pronounced.	The lead author for this sub-section is not an expert of plastics. We use the case of Dow here is just to present that individual companies can fully engage in CE by various efforts. We are open if you can provide more convincible cases.	Cédric PHILIBERT	Consumer Product Safety Association	Japan
2367	26	43	27	29	For industrial parks can you add that transportation of material can be one benefit of industrial parks; also that co-siting new industrial parks seem like they could be an opportunity for the future, for example, siting a park that is in an area of high wind and solar resources but still close to centers of urban demand.	We added one statement in Line 8 of Page 27, where it reads:"as well as reduced/avoided transportation costs from byproducts exchanges among tenant companies"	Jeffrey Merrifield	Lawrence Berkeley Lab	United States of America
57297	26	43	26	45	Suggested re-write: "Industrial parks first appeared in Manchester, UK, at the end of the 19th century and they have been implemented in industrialised countries for maximizing energy and material efficiency, which has also merit for CO2 emissions reduction, as stated well in AR5. Industrial parks ..." Note that industrial parks are also prevalent in China and possibly other emerging economy countries, so the statement that they have been "implemented in industrialized countries" might need to be modified also.	We have accepted your suggestion and revised this sentence.	Ann Jessica Johnson	U.S. Department of State	United States of America
57299	26	48	26	48	The Geng and Zhao (2009) reference is too old for the AR6. Find a more recent citation.	We have changed a new literature, which provides a similar statement.	Christian Breyer	U.S. Department of State	United States of America
85101	26	43	27	29	This is a very long paragraph and the phrasing is occasionally awkward - needs to be broken up and edited for style.	We have re-edited the whole sub-section.	Célia Sapart	Australian Industry Group	Australia

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
2371	27	1	27	29	Discussion in industrial parks would benefit from a few examples of how CE is achieved. Energy / GHG savings from reduced transportation emisssions or waste heat from one plant being used as process heat for another plant is not really CE at the product level.	This is mainly about industrial symbiosis and CE is covered in Ch5	Government of United States of America	Lawrence Berkeley Lab	United States of America
57301	27	1	27	10	Discussion of meso-level CE/industrial parks is interesting but neglects to address the challenges of inter-firm contractual challenges and uncertainties that have inhibited development of these relationships in some countries (e.g., U.S.). Legal reforms may be needed to address these implementation barriers.	We added one more sentence at the end of this paragraph, in which it reads: "However, challenges exist for industrial symbiosis activities, such as the inter-firm contractual uncertainties, the lack of synergy infrastructure, and the irrational regulations (such as the prohibition of direct reuse/recycling of some toxic/hazardous wastes). Therefore, necessary legal reforms are needed to address these implementation barriers."	Government of Norway	U.S. Department of State	United States of America
86787	27	2	27	3	There is no multilateral agreement on the concept "green supply chain", so we suggest deleting it as its scope is not clear. In defect, we propose to replace it by "sustainable supply chain", in line with the 2030 Agenda.	We changed this accordingly.	Government of Argentina	Ministry of Environment and Sustainable development of Argentina	Argentina
70439	27	19	27	23	Many of the listed measures are not clearly related to the circular economy, but rather to fuel switching and/or energy efficiency and some are part of the Figure on Material Efficiency. Consider better defining material efficiency from circular economy and relocate measures to the appropriate sections.	For Kana	Pietro Guarato	European Union (EU) - DG Research &amp	Belgium
57303	27	19	27	21	It's not clear how "increase the share of natural gas consumption, reduce the GHG emission factor of electricity grid, and improve the average efficiency of industrial coal-fired boilers" are circular economy (CE) measures. Clarify.	For Kana	Eve Tamme	U.S. Department of State	United States of America
57305	27	19		22	Not sure if these would be counted as CE. Seems to be just conventional fuel switching and efficiency improvement.	For Kana	Eve Tamme	U.S. Department of State	United States of America
85103	27	19	27	21	The note about the role in industrial emissions reduction of increased gas share of power generation and improved coal boiler efficiency is highly time- and context-dependent - probably needs to be qualified as "in the earlier stages of industrial decarbonisation" or similar.	For Kana	Government of Norway	Australian Industry Group	Australia
57307	27	21	27	23	Provide the base or starting year for this savings information. The 111 MtCO2eq savings are from measures implemented between 20?? and 2030: "The case of China shows a great potential of implementing these measures, estimating 111 million tonne CO2 equivalent will be reduced in 213 national-level industrial parks in 2030 (Guo et al., 2018)."	The base year is 2015. We have revised in the main text accordingly.	Yuan Yao	U.S. Department of State	United States of America
2369	27	30	27	49	The discussion on CE and sharp reductions in either material demand or virgin material demand suggests that industry employment could be impacted negatively. Excess labor could be a problem unless it is planned for or unless other employment opportunities are envisioned. It is worth mentioning this and in general to have some discussion of what are potential tradeoffs or barriers to more CE. If these are not well studied it is worth noting that also.	For Kana	Mitsutsune Yamaguchi	Lawrence Berkeley Lab	United States of America
14821	27	36	27	45	The potential for secondary route should be balanced, as secondary steel usage is limited by : 1) the quality of the steel (that is degraded with recycling), 2) by the level of maturity of steel stock per capita (IEA Energy Technology Perspectives Report - 2020)	For Kana	Rebecca Dell	Indépendant consultant	France
57309	27	37	27	38	"For instance, the Kawasaki urban symbiosis efforts can save over 114,000 tons of CO2 emission annually (Geng et al., 2010).": The reference is old for the AR6. Did this happen or is this a simulation result since it says "can"? If a simulation result, state this in the sentence and also note for what year these savings are for. If the savings are for before the publication date of 2010, it would be good to have more recent information if possible.	You are right, this result is a simulation result. We did list a wrong literature. This simulation result is from a paper written by Satoshi and his colleagues and was published in 2017. We changed the reference accordingly.	Yuan Yao	U.S. Department of State	United States of America
3693	27	42			estimates -> estimate	We revised accordingly.	Célia Sapart	Mines Saint-Etienne	France
57311	27	42	28	10	Starting with "Moreover" (which should be removed), this should be a new paragraph since the following sentences are about a different topic than the prior sentences.	We revised accordingly.	Christian Breyer	U.S. Department of State	United States of America
3651	27	46	27	49	"CO2 emission from steel sector will be reduced by 56% assuming the CE,…and the export of steel products is halved (LCS 2018a)": This might be the case for Japan, but exported scraps are used as low carbon steel source in other countries so the same CO2 reduction must be realized in outside the border of Japan and net global emission will be remain the same.	For Kana	Government of Norway	JFE Steel Corp.	Japan
43225	28	4	28	10	It has been suggested that the overreliance on incineration for other Nordic countries that follow a similiar model of waste management than Germany has created a lock in situation for these countries that becomes an obstacle to advance the circular economy objectives. The Nordic Council of Ministers, which involves the regional collaboration of Denmark, Finland, Iceland, Norway, Sweden, and the Faroe Islands, Greenland and Åland, published the report Analysis of Nordic regulatory framework and its effect on waste prevention and recycling in the region (2019). The main recommendations for Nordic countries (p.9) were: - shift away from incineration, towards more recycling (and for Iceland who doesn't incinerate much, shift away from landfilling) - increase separate door-to-door collection for recyclables and organic waste (yes, they're not great on this). - increase taxes/implement bans on the incineration of recyclables and organic waste - increase recycling and composting/anaerobic digestion infrastructure - implement pay-as-you-throw schemes.	For Kana	Government of United States of America	Zero Waste Europe/University of Manchester	United Kingdom (of Great Britain and Northern Ireland)
57313	28	6	28	7	Food waste prevention might have better results on the producing and selling side than on the consumer side.	For Kana	Amory B. Lovins	U.S. Department of State	United States of America
57315	28	9	28	9	Suggested re-write: "… background conditions, local policies and myriad other factors influencing material flows from the …"	Revised accordingly.	Amory B. Lovins	U.S. Department of State	United States of America
3697	28	12			Very important comment : In section 11.3.4, You do not mention organisational approaches such that the ones available in planning and scheduling community, or operational research widely. For instance, without being exhaustive, you can reduce peak power usage (Bruzzone et al., 2012; Kemmoe et al., 2017) by selecting proper starting times of operations. Such approaches may be useful when considering smoothening requirements and help manage smart grids. You can also reduce Total Energy Consumption by reducing idle times of machining operations (Mouzon & Yildirim, 2008; Salido et al., 2016; Wang et al., 2018), or integrate Time of Use pricings directly at the operational level ((Gong et al., 2019; Zhai et al., 2017)). As you mention, we are reaching limits of technological possibilities, and organizational measures can be achieved without large investments (Biel & Glock, 2016). Biel, K., & Glock, C. H. (2016). Systematic literature review of decision support models for energy-efficient production planning. Computers & Industrial Engineering, 101, 243–259. https://doi.org/10.1016/j.cie.2016.08.021 Bruzzone, A. A. G., Anghinolfi, D., Paolucci, M., & Tonelli, F. (2012). Energy-aware scheduling for improving manufacturing process sustainability: A mathematical model for flexible flow shops. CIRP Annals - Manufacturing Technology, 61(1), 459–462. https://doi.org/10.1016/j.cirp.2012.03.084 Gong, X., De Pessemier, T., Martens, L., & Joseph, W. (2019). Energy- and labor-aware flexible job shop scheduling under dynamic electricity pricing: A many-objective optimization investigation. Journal of Cleaner Production, 209, 1078–1094. https://doi.org/10.1016/j.jclepro.2018.10.289 Kemmoe, S., Lamy, D., & Tchernev, N. (2017). Job-shop like manufacturing system with variable power threshold and operations with power requirements. International Journal of Production Research, 55(20), 6011–6032. https://doi.org/10.1080/00207543.2017.1321801 Mouzon, G., & Yildirim, M. B. (2008). A framework to minimise total energy consumption and total tardiness on a single machine. International Journal of Sustainable Engineering, 1(2), 105–116. https://doi.org/10.1080/19397030802257236 Salido, M. A., Escamilla, J., Barber, F., Giret, A., Tang, D., & Dai, M. (2016). Energy efficiency, robustness, and makespan optimality in job-shop scheduling problems. Artificial Intelligence for Engineering Design, Analysis and Manufacturing, 30(03), 300–312. https://doi.org/10.1017/S0890060415000335 Wang, S., Wang, X., Yu, J., Ma, S., & Liu, M. (2018). Bi-objective identical parallel machine scheduling to minimize total energy consumption and makespan. Journal of Cleaner Production, 193, 424–440. https://doi.org/10.1016/j.jclepro.2018.05.056 Zhai, Y., Biel, K., Zhao, F., & Sutherland, J. W. (2017). Dynamic scheduling of a flow shop with on-site wind generation for energy cost reduction under real time electricity pricing. CIRP Annals - Manufacturing Technology. https://doi.org/10.1016/j.cirp.2017.04.099	Agreed and partly accepted: improved.	Alex Rau	Mines Saint-Etienne	France
84885	28	12	31	25	The EE section in particular needs an edit by someone with native proficiency in english, as it is full of malapropism and strange word choice	improved	Edgar Hertwich	ClimateWorks Foundation	United States of America
57317	28	12	28	24	While technologies are important for increasing the energy efficiency of industrial processes, not all plants have the same amount of efficient technology and many facilities can still increase efficiency through low-cost opportunities and through actively managing energy through Strategic Energy Management programs. Suggest including some language around the opportunities that are still available through existing technologies and on efficiency gains that can be expected with an organizational Strategic Energy Management program for energy. Potential text could include: - While a massive reduction in carbon within the industrial sector requires more than just implementing existing technologies, for the many plants that are operating inefficiently, using already accepted energy efficiency technologies and processes, such as variable speed drives on motors, LED lighting, insulation, continuous commissioning, etc., can still make significant impacts. - In an organization setting, the role that management priorities and procedures have in effecting outcomes cannot be discounted. Having organizational policies around energy efficiency, internal and public facing goals, and staff whose role include managing energy will more likely help an organization to improve its efficiency than one without this focus. References: Focusing and improving traditional energy efficiency strategies: https://doi.org/10.1016/j.tej.2019.106620 (Notes that Strategic Energy Management programs can achieve savings of 4-5% per year) Plant-level Goal and Recognition Programs as a Strategic Energy Management Tool: https://www.aceee.org/files/proceedings/2017/data/polopoly_fs/1.3687835.1501159018!/fileserver/file/790245/filename/0036_0053_000055.pdf	Thanks. Accepted.	Durwood Zaelke	U.S. Department of State	United States of America
57319	28	12	31	23	Section 11.3.4 is wholly inadequate. Get a contributing author who can help improve this section. As it is, it is not acceptable for publication.	improved	Gabrielle Dreyfus	U.S. Department of State	United States of America

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
57321	28	12	31	23	The framing of energy efficiency in the section is fairly limited and unfocused, missing many important macro energy efficiency opportunities while focusing on a couple of niche examples. Suggest a significant redraft of this section with a more focused and strategic structure identifying big systemic opportunities, then including some illustrative examples. These macro elements might include: - Energy management - Industry 4.0/Smart Manufacturing/IIoT (enables many of the other opportunities) - Grid responsive energy management - Modularization of process systems - Thermal process integration - Waste heat recovery - Motor systems optimization - Flexible manufacturing - Supply chain optimization An important element that is missing is the growing trend toward strategic energy management, as reflected by various efforts included the ISO-50001 energy management standard. This organizational structure provides important insights into how energy (and potentially other attributes such as carbon) are being used within an organization, can identify efficiency and waste reduction opportunities, and create a framework for integration of IIoT and alternative technologies such as electrification into manufacturing plants. A couple of other elements that are missing in this discussion are a trend in industrial energy efficiency to shift the focus from equipment efficiency to focus on process optimization and further to inter-process optimization, which is enabled by ICT/Smart Manufacturing, and an increasing focus on the role of industrial facilities in integrating into the electric grid with response control strategies that support expanded deployment of variable electric resources and in some case allow the use of curtailed renewable generation resources. This again represents a transition in the vision of energy efficiency from simply reductions in energy use to a dynamic energy use optimization across time and location. Energy efficiency also embodies a shift from central systems (e.g., boilers) to more modular system that allow for more precise control of systems and reduced waste from plant-wide systems. This robust and more comprehensive approach also affords opportunities for the transition to lower carbon process technologies, such as electrification (see https://www.aceee.org/research-report/ie2002). Finally, industrial motor system optimization remains an important energy efficiency opportunity with electric motors systems accounting for on the order of two-thirds of industrial electricity use. This involves both efficiency upgrades and motor fleet management, as well as a transition to advanced motor technologies that offer enhanced performance, control and optimization opportunities. LBNL is currently updating information on this opportunity following on a release of a U.S. motor system market report earlier this year (https://escholarship.org/uc/item/42f631k3).	First point of comments have been included and the second part regarding grid connect with response control is not the matter in this section. The latter parts are accepted.	Philippe Tulkens	U.S. Department of State	United States of America
57323	28	12	31	25	This discussion of energy efficiency would benefit from a little more attention to operational improvements, in addition to the extensive discussion of capital improvements. Also, Figure 11.8 could be made both smaller and clearer by using box or whisker plots to show ranges and averages instead of separate bars for minimum, maximum, and average. Electricity consumption by the cement industry seems unnecessary to include.	Revised.	Yuan Yao	U.S. Department of State	United States of America
84889	28	12	31	25	It was very odd that the EE section did not discuss operational improvements, but only talked about capital improvements.	Included.	Government of Norway	ClimateWorks Foundation	United States of America
84891	28	12	31	25	It was also a missed opportunity to not discuss the potential trade-offs between EE and process change, for example if one makes a big capital investment in a more efficient conventional process, it might be harder to justify scrapping the process unit to replace it with a zero-emissions process in the near future.	Process change itself become opportunity for energy efficiency. Normaly the cost effective BAT as possible will be installed.	NAOKI AOKI	ClimateWorks Foundation	United States of America
84893	28	12	31	25	It would have been more useful to provide an overall quantified assessment of potential (not just "large" as on p30, l14) instead of the random collection of EE examples on p31	This section does not deal the overall potential which is in other sections.	Mark Preston Aragones	ClimateWorks Foundation	United States of America
57329	28	13			"Industrial energy efficiency is A number one mitigating" should read "Industrial energy efficiency is THE number one mitigating"	OK	Government of Norway	U.S. Department of State	United States of America
57325	28	13	28	13	Here authors state that "Industrial energy efficiency is a number one mitigating option in the shorter term" (o reference is supplied). However, on page 9, lines 23-24, they say: "Energy efficiency dominates in the short- and medium-term and potentially long-term (in the range of 10-40% by 2050) (IPCC, 2018; Crijns-Graus et al., 2020; IEA, 2020a)." And further, on page 62, lines 33-35, in reference to the IEA Clean Technologies Scenario: "Energy efficiency improvements and deployment of BATs contribute 46% to cumulative emission reduction in 2018-2060, while fuel switch (15%), material efficiency (19%) and deployment of innovative processes (20%) provide the other part." Modify the statement on page 28, line 13, to be consistent with the other statements in the chapter which happen to be fully referenced.	Revised.	Government of Norway	U.S. Department of State	United States of America
57327	28	13	28	13	Energy efficiency will be important for longer than the short term. Do not minimize it.	Misunderstood. Sentense improved.	Government of United States of America	U.S. Department of State	United States of America
57331	28	14	28	14	Tanaka (2011) is too old a cite for AR6. Provide more recent references.	Relatively old but safficiently comprehensive for discussion here. If there is a new additional points in addition, willingly to use it, but most of published papers recently does not cover them.	Government of United States of America	U.S. Department of State	United States of America
57333	28	16	28	19	The bullet on page 11-28 is largely a compilation of buzz words. It should focus not on terms but fundamental concepts of smart manufacturing. Also note that the term of art in the U.S. is Smart Manufacturing. The discussion of Industry 4.0 reflects a fairly limited vision of what Industry 4.0/Smart Manufacturing/IIoT could enable. The work of CESMII (https://www.CESMII.org) and others has developed a much more robust vision of the impacts these technologies could have. In particular, the importance of developing process simulations -- digital twins -- allow for the continuous optimization of a process or multiple interconnected processes (e.g., plant wide multi-process optimization). The deployment of IIoT across supply chains minimizes waste, maximizes product quality, and assists with product tracking (see forthcoming U.S. DOE Industrial Decarbonization Roadmap and work by Ethan Rogers such as https://www.eceee.org/library/conference_proceedings/eceee_Industrial_Summer_Study/2018/1-policies-and-programmes-to-drive-transformation/integrating-smart-manufacturing-and-strategic-energy-management-programs/ and https://www.aceee.org/research-report/ie1403). These comments also apply to Section 11.3.4.2.	Revised.	Government of United States of America	U.S. Department of State	United States of America
57335	28	16	28	24	This section completely ignores the role that stronger energy management practices can play in improving energy efficiency. Recommend adding a bullet: "encouraging the adoption of stronger energy management practices that focus on continuously improving energy performance and optimizing existing equipment and systems".	Thanks. Accepted.	Government of United States of America	U.S. Department of State	United States of America
82749	28	16	28	18	these digitalization concepts could be reinforced in the digitalization discussion/evidence occuring in other chapters (5, 16)	Revised.	Government of United States of America	Northwestern University	United States of America
57337	28	20	28	21	What is "moral efficiency degradation"? Define or use a more commonly understood term.	Revised.	Government of United States of America	U.S. Department of State	United States of America
29771	28	22	28	22	Please consider making some reference to the issue of lock-in here. The construction of new more efficient but still emission intensive installations might prove counterproductive in an ambitious mitigation effort (as discussed on page 11-31, lines 39 – 43, 11-44, lines 18 – 20, 11-70, from line 1 to 11-71 line 4, and elsewhere).	Not in this section.	Philippe Tulkens	Norwegian Environment Agency	Norway
57339	28	25	28	26	This sentence needs a re-write: "There are two parallel processes: technological improvement efforts leading to relatively slow energy efficiency BATs progress and faster one - SECs decline towards BATs."	Revised.	Edgar Hertwich	U.S. Department of State	United States of America
3695	28	26			check sentence : both slow down ?	Revised.	Government of Germany	Mines Saint-Etienne	France
57341	28	28	28	29	Given that Figure 11.8 provides BATs for only three industrial commodities (alumina, clinker, and cement), authors cannot refer to this figure to broadly state "SECs for many basic primary materials approach BATs". The statement may be true, but no references are provided to support it, which is an IPCC requirement.	Accepted.	Government of United States of America	U.S. Department of State	United States of America
86837	28	29			With regards to the phrase "This highlights the need to push towards circular economy", there is a need to add the following at the end of this sentence: "AS ONE OF THE AVAILABLE MEANS, AMONG OTHERS, TO ACHIEVE SUSTAINABLE DEVELOPMENT, AS DEFINED BY EACH COUNTRY ACCORDING TO ITS NATIONAL POLICIES AND PRIORITIES", due to the fact that the circular economy is one of the available means and tools, among others, to achieve sustainable development, according to the national policies and priorities defined by each country.	Accepted.	Government of Argentina	Ministry of Environment and Sustainable development of Argentina	Argentina
2255	29	1	29	1	In figure 11.8, there is no bar graph for BAT in chemicals	Data limitation.	Government of United States of America	Hongik University	Republic of Korea
16555	29	1	29	1	In figure 11.8, there is no bar graph for BAT in chemicals	same comment above.	Government of United States of America	Korea Meteorological Administration (KMA)	Republic of Korea
57351	29	1		7	Hydrogen itself needs energy to make, and so does storage. A lifecycle-based assessment will be needed. Are there articles discussing it? In addition, what will be the scale? Can global manufacturing capacity catch up? At what cost?	Revised.	Tennant Reed	U.S. Department of State	United States of America
15559	29	1	29	1	Figure 11.8 for metals are difficult to read. It seems that the average value for year 2000 in grey belongs to the crude steel sector while it might be for the aluminium sector, i.e. the vertical bar is on the right side of the average 2000 value while it should be on the left-side. Same for alumina. Other problem is that they are two different shades of blue for the crude steel sector but no hint of which is what. Legend needed.	Accepted.	Kornelis Blok	MINES ParisTech, Total	France
15559	29	1	29	1	Figure 11.8 for metals are difficult to read. It seems that the average value for year 2000 in grey belongs to the crude steel sector while it might be for the aluminium sector, i.e. the vertical bar is on the right side of the average 2000 value while it should be on the left-side. Same for alumina. Other problem is that they are two different shades of blue for the crude steel sector but no hint of which is what. Legend needed.	Figure was edited along suggestions	Kornelis Blok	MINES ParisTech, Total	France
15863	29	1	29	1	Period is needed after BATs.	Figure was edited along suggestions	Philippe Waldteufel	KIET(KOREA INSTITUTE FOR INDUSTRIAL E	Republic of Korea
15863	29	1	29	1	Period is needed after BATs.	Thanks.	Philippe Waldteufel	KIET(KOREA INSTITUTE FOR INDUSTRIAL E	Republic of Korea
82753	29	1	29	1	the authors mention several times that efficiency is approaching theortical limits, so can these limits be drawn into the figure to give a sense of how far away BAT values are from theoretical minimum values? Or perhaps at least state what are the mimimum acheivable values in the text, which can probably be extracted from the cited sources?	Figure was edited along suggestions	Philippe Tulkens	Northwestern University	United States of America
82753	29	1	29	1	the authors mention several times that efficiency is approaching theortical limits, so can these limits be drawn into the figure to give a sense of how far away BAT values are from theoretical minimum values? Or perhaps at least state what are the mimimum acheivable values in the text, which can probably be extracted from the cited sources?	Accepted.	Philippe Tulkens	Northwestern University	United States of America
82753	29	1	29	1	the authors mention several times that efficiency is approaching theortical limits, so can these limits be drawn into the figure to give a sense of how far away BAT values are from theoretical minimum values? Or perhaps at least state what are the mimimum acheivable values in the text, which can probably be extracted from the cited sources?	Figure was edited along suggestions	Philippe Tulkens	Northwestern University	United States of America
57343	29	1	29	6	Figure 11.8 does not add value to this section and may misrepresent the overall importance of energy efficiency. While some processes may be approaching theoretical limits, the opportunities for energy efficiency are increasingly in the implementation of technologies in systems and the optimization of these systems, rather than in the inherent efficiency of the technologies. Experience from industry suggests that significant energy efficiency potential continues to exist from system optimization. Deleting this figure.	Improved.	Government of United States of America	U.S. Department of State	United States of America

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
57345	29	1	29	7	Since all of the graphics do not provide BATs, the title for this figure should be changed to something like: ""Energy intensities compared to best available technologies, averages, minimums, and maximums."" For the metals comparison chart: 1) For steel, are the units GJ/t crude steel? Or GJ/t rolled steel? Or something else? 2) For crude steel, authors show the average for 2000 and 2018. Are these average GJ/t crude steel for all steel making processes combined? 3) The BAT for steel that was in the FOD version of Figure 11.8 has been removed. Can authors provide any BATs for the different steel processes? If not, then the title of this figure definitely needs to be modified. 4) For aluminum, what process are the average, minimum, and maximum values for? Is this only for primary production or for primary and recycled production together? These must be labeled. 5) What is the unit for the cement and clinker chart? GJ/t cement? GJ/t clinker? It's very important and makes a difference with these products. 6) For the cement values (not the cement-electricity values), are these just for fuels or is this fuels + electricity? 7) For the cement-electricity label, t of what? Cement or clinker? 8) For the chemical chart, what are the units? t of what? 9) Define HVC somewhere. 10) No BATs available?	Accepted.	Government of United States of America	U.S. Department of State	United States of America
57345	29	1	29	7	Since all of the graphics do not provide BATs, the title for this figure should be changed to something like: ""Energy intensities compared to best available technologies, averages, minimums, and maximums."" For the metals comparison chart: 1) For steel, are the units GJ/t crude steel? Or GJ/t rolled steel? Or something else? 2) For crude steel, authors show the average for 2000 and 2018. Are these average GJ/t crude steel for all steel making processes combined? 3) The BAT for steel that was in the FOD version of Figure 11.8 has been removed. Can authors provide any BATs for the different steel processes? If not, then the title of this figure definitely needs to be modified. 4) For aluminum, what process are the average, minimum, and maximum values for? Is this only for primary production or for primary and recycled production together? These must be labeled. 5) What is the unit for the cement and clinker chart? GJ/t cement? GJ/t clinker? It's very important and makes a difference with these products. 6) For the cement values (not the cement-electricity values), are these just for fuels or is this fuels + electricity? 7) For the cement-electricity label, t of what? Cement or clinker? 8) For the chemical chart, what are the units? t of what? 9) Define HVC somewhere. 10) No BATs available?	Some suggestions were accepted.	Government of United States of America	U.S. Department of State	United States of America
57347	29	1	29	7	For Figure 11.8, the IEA's Iron and Steel Technology Roadmap (page 76) provides this information which might be helpful: "Incremental change can be achieved through improvements in the operation of equipment and by upgrading process equipment to commercially available best available technology (BAT),[6] which reduces the energy demand required per tonne of process output. An energy saving of around 20% per tonne of crude steel can be achieved by improving operational efficiency and adopting BAT for all the units of the BF-BOF production pathway, relative to the global average energy intensity for this route today." Footnote 6 states: "The energy-saving potential of implementing BAT differs on a site-by-site basis given the specific characteristics of each facility (e.g., relative size of existing equipment, operating conditions, plant layout). Our analysis is based on approximations on the energy-saving potential that was obtained in best-performing state-of-the-art facilities."	Accepted	Philippe Tulkens	U.S. Department of State	United States of America
57349	29	1	29	7	Figure 11.8 remains so problematic that it should be deleted. It is unclear, poorly labeled, doesn't show what it is purported to show, and generally more confusing than helpful. If the authors want to pull out a few of the key data points to show the distance between one or two processes and BAT, then that could be added to the text. As it is, this figure is not up to the quality required by an IPCC report.	Accepted.	Government of United States of America	U.S. Department of State	United States of America
43957	29				Figure 11.8 Energy efficiency potential for approaching best available technologies (BATs) energy accounting for cement and clinker is from a 2012 report that is a literature review. It is not supported by current data or operational experiences and its inclusion in this report is unwarranted.	Updated.	Government of France	Portland Cement Association	United States of America
72833	29		29		Does the figure show "potential" or only the spread of energy effiicient plants ? It is not clear. Maybe include the estimated BAT itself beside each case or clarify the legend	Accepted.	Tennant Reed	EE-Consultant	France
84887	29		29		Figure 11.8 could be much more compact and clearer by the simple expedient of using an indicator of range instead of separate bars for min, max, avg. Also, why is it significant to include the electricity intensity of cement--no one cares about that metric.	Accepted.	Philippe Tulkens	ClimateWorks Foundation	United States of America
57353	30	1	30	37	The energy efficiency in heat discussion needs more structure, focusing on the energy efficiency opportunities in process heat, perhaps as follows: - Insulation - Matching of process needs to temperature resources - Thermal integration that enables waste heat recovery and use of heat pumps (also known as thermal pinch) - Transition from centralized thermal systems (e.g., boiler) to modular process heating technologies - Electrification of process heating (obviously overlaps with electrification section, but important to ensure that process optimized before it is electrified and that appropriate controls are implemented) - Optimization of drying (opportunities for improved drying efficiency through the application of multiple, cascading technologies to address the different phase of dewatering and drying). The introduction of a discussion of alternative and low-carbon fuels seems out of place in this section. There is certainly an overlap, as there is with electrification, but there needs to be an explicit linkage articulated. See the discussion on electrification of thermal processes in https://www.aceee.org/research-report/ie2002. There will also be an in-depth discussion in the forthcoming U.S. Department of Energy Industrial Decarbonization Roadmap report, anticipated in Spring 2021, well before the WGIII AR6 literature cutoff date (accepted).	Thanks. Tried to integrate the points into the section/	Government of United States of America	U.S. Department of State	United States of America
57355	30	1	30	37	To achieve dramatic improvements in industrial thermal processing (also known as process heating), look at four different technology pillars: (1) use of low thermal budget transformative technologies, (2) use of alternative or hybrid technologies while maintaining or improving upon the current process parameters (e.g., reaction temperature, product specificity), (3) use of transformative supplemental technologies (e.g., smart manufacturing, Internet of Things [IoT], artificial intelligence [AI], digital twin), and (4) use of waste heat management (i.e., reduction of energy use, recycling of waste heat into the existing process, and waste heat recovery), which allows use of heat discharged from a process to supply heat to another process, to elevate quality (temperature) of the heat, for use in power generation, and for cooling.	Thanks.Included.	SAI MING LEE	U.S. Department of State	United States of America
57661	30	1	30	37	To achieve dramatic improvements in industrial thermal processing (also known as process heating), look at four different technology pillars: (1) use of low thermal budget transformative technologies, (2) use of alternative or hybrid technologies while maintaining or improving upon the current process parameters (e.g., reaction temperature, product specificity), (3) use of transformative supplemental technologies (e.g., smart manufacturing, Internet of Things [IoT], artificial intelligence [AI], digital twin), and (4) use of waste heat management (i.e., reduction of energy use, recycling of waste heat into the existing process, and waste heat recovery), which allows use of heat discharged from a process to supply heat to another process, to elevate quality (temperature) of the heat, for use in power generation, and for cooling.	Same as above.	Government of United States of America	U.S. Department of State	United States of America
70441	30	2	30	37	A core problem in the current energy-intensive processes is their high temperature. Processes for the production of steel, ammonia/methanol/hydrogen/syngas and high value chemicals have an endothermic core reaction at 800+°C. The heat demand of the other processes is coverd by the waste heat in the product. Because of the excess of high temperature heat, such processes have no demand for low temperature heat, which is wasted as a consequence. I suggest to highlight the benefits of adapting new, intensified processes at a lower temperature. These have the benefit of higher yield and efficiency, the elimination of high temperature demand and a much increased potential for the reuse of low temperature waste heat. A similar point can be made for energy efficient separations, for example membrane technologies instead of evaporation/distillation.	The former part was addressed already. Latter needs literature.	Government of United States of America	European Union (EU) - DG Research & Innovation	Belgium
57357	30	4	30	8	This section is called "energy efficiency improvement at heat use." Some of the text discusses electrification, biomass, and green hydrogen, none of which are energy efficiency measures.	Revised.	Government of Japan	U.S. Department of State	United States of America
57359	30	6	30	6	Explain what is meant by grey, blue, and green hydrogen. Not all readers will understand what these terms mean.	Revised.	Christian Breyer	U.S. Department of State	United States of America
82751	30	6	30	6	can you elaborate on why cost would escalate when moving from grey to blue to green H2 since some may consider these supply-side costs (perhaps affecting feedstock prices to industry?) rather than demand-side investments (unless you assume on-site H2 production?). either way some elaboration here would help.	Not in this section.	Government of France	Northwestern University	United States of America
57361	30	7	30	8	It is important that all biomass is produced sustainably and that sustainability can be verified.	Not in this section.	Edgar Hertwich	U.S. Department of State	United States of America
69857	30	8	30	11	I would add the emerging technology of supplying constant superheated air or steam from variable renewable electricity supply through compact heat storage technology in molten salts, vulcanic rocks, steel or refractory bricks, currently up to 650°C (e.g. Siemens Electric Thermal Energy Storage, Lumenion) and soon up to 1000°C or even 1600°C (Rondo Energy), with excellent return efficiency and costs significantly lower than any electricity storage technology.	No supporting literature provided	Alex Rau	Institut Français des Relations Internationales	France
57363	30	10			Errant period ["."] in middle of sentence.	Revised.	Government of United States of America	U.S. Department of State	United States of America
57365	30	10			Remove random "to" from sentence that reads "and needs to sizable".	Revised.	Philippe Waldteufel	U.S. Department of State	United States of America
74919	30	10	30	10	Remove fulstop between the following words 'process .and'	Revised.	Government of Japan	Kenya Meteorological Service	Kenya
57367	30	11	30	13	This sentence is syntactically challenged. Also, why is Figure 11.8 referenced? Explain or remove the callout to the figure.	Revised.	Richard Bohan	U.S. Department of State	United States of America
69859	30	14	30	29	Beside industrial heat pumps, a very effective way of using wasted heat is based on mechanical vapour recompression. By avoiding the loss of latent heat by condensation, steam recompression acts as a highly efficient heat pump with a coefficient of performance between 5 and 10. The potential is considerable, in particular in the chemical industries, see e.g. Bazzanella, M. and F. Ausfelder, 2017, op.cit. Heat pumps and MVr avoid wasting heat arising from some processes at temperature levels to low for other processes by uplifting the temperature levels to whatthese processes require.	Accepted.	Government of United States of America	Institut Français des Relations Internationales	France
69861	30	15	30	17	You could mention here Philibert, 2017, op.cit. and more importantly Madeddu 2020, op.cit.	Accepted.	Government of United States of America	Institut Français des Relations Internationales	France
70443	30	16	30	19	Sentence unclear. Consider rewriting to "..., with thermal conductivity only half of what is traditionally achieved by heat resistant bricks..."	Revised.	Government of United States of America	European Union (EU) - DG Research &amp	Belgium
72835	30	18	30	18	appalled ?	Revised.	Government of United States of America	EE-Consultant	France
43921	30	39	31	7	Artificial Intelligence (AI) is a big part of Industrial 4.0 and includes some techniques already discussed in this section. AI has much more applications as discussed here that can specifically support the reduction of cost, energy, and GHG emissions and even support the development and adoption of renewable energy. Here is a reference: Applications of artificial intelligence-based modeling for bioenergy systems: A review. GCB Bioenergy. https://doi.org/10.1111/gcbb.12816	Not about industry.	Cécile Seguineaud	Yale University	United States of America
57369	30	40	30	40	What is the Industry 4.0 concept? Do the references at the end of the next sentence address this concept? If not, provide a reference for this sentence.	Revised.	Célia Sapart	U.S. Department of State	United States of America
51309	30	46			"[R]educing the idle times for both men and robots" - Is it desirable to foster efficiency in this way from an environmental point of view: ? Accelerating unsustaianble production is aggravating the problem, not solving it.	Rejected.	Deepak PANT	Institute for Advanced Sustainability Studies (IASS), Potsdam	Germany
57371	30	47	30	47	Use "staff" or "workers" or another term instead of "men".	Revised.	Jim O'Brien	U.S. Department of State	United States of America
57373	31	1	31	7	The last sentence of this first paragraph on page 31 is a repeat of lines 1-2.	Revised.	SAI MING LEE	U.S. Department of State	United States of America
51311	31	3			Increasing productivity and optimizing processes does not imply better environmental performance	Not accepted.	Government of United States of America	Institute for Advanced Sustainability Studies (IASS), Potsdam	Germany

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
51313	31	9			Instead of blindly fostering technological progress, a rigorous net benefit analysis/life cycle analysis should be conducted about if and how an upgrade, e. g. digitalisation in an industrial plant, is beneficial from an environmental point of view. When will the material and energy input be amortized by the savings through efficency increases?	Beyond this section.	Rebecca Dell	Institute for Advanced Sustainability Studies (IASS), Potsdam	Germany
57375	31	9	31	23	This whole section is incredibly weak and should be completely re-written. How can a section on energy efficiency technology progress start with "The pneumatic strain energy accumulator"? This is one very specific example. Instead, this section should discuss energy efficiency technology progress more broadly, then give some examples. Have there been new advances in energy efficiency technologies? Has adoption of energy efficiency technologies increased/decreased? What about costs? Then give some examples.	Revised.	Rebecca Dell	U.S. Department of State	United States of America
57377	31	9	31	23	Not sure what the point of this section is. These seem like specific examples but not sure why space is used for this while other larger-scale opportunities are overlooked. Suggest this section be deleted or completely reworked focusing on the largest opportunities. See the forthcoming U.S. Department of Energy Industrial Decarbonization Roadmap and the industrial chapter of U.S. House of Representatives Select Committee on the Climate Crisis report (https://climatecrisis.house.gov/report).	Revised	Rebecca Dell	U.S. Department of State	United States of America
57379	31	10	31	15	This paragraph seems like an example of modifying processes to improve energy efficiency, but it is not clear. The second paragraph could possibly stand alone in this section.	Revised	Hiroyuki Tezuka	U.S. Department of State	United States of America
57381	31	10	31	23	Rather than talking about a better compressed air system, this section should highlight some of the barriers to efficient equipment utilization. There are still persistent barriers that need to be addressed. These include things such as: - Lack of energy management program to identify and implement efficiency upgrades - Corporate finance policies that discourage investment in equipment with pay-back periods greater than 2 years - Risk aversion to trying new approaches or technologies - Lack of awareness of more efficient options.	Revised.	Government of United States of America	U.S. Department of State	United States of America
70445	31	10	31	15	It is unclear to the reader why these two examples have been chosen. Compressed air represents only a minor part of the energy use of energy-intensive industries, although it can be more substantial for smaller manufacturing companies. I suggest to highlight that the development of heat pumps, mechanical vapour recompression and sorption based technologies can enable the reuse of waste heat where this was previously not technically or economically feasible before.	Revised.	Rebecca Dell	European Union (EU) - DG Research & Innovation	Belgium
82755	31	10	31	15	suggest deleting this extremely specific example for one technology in one industry and instead commenting more broadly on the progress made in other processes/technologies not depicted in fig 11.8, such as industrial boilers, motors, compressed air systems, etc. which largely go unmentioned in the whole chapter but are very important for the light industries.	Revised.	Government of United States of America	Northwestern University	United States of America
70447	31	16	31	19	I suggest to further detail the financial aspect: companies have limited investment budgets and investments in energy efficiency often compete with other investments that are more profitable, for example capacity extensions. Moreover, investments in energy efficiency cannot be financed with debt, since the collateral (the factory) is already used in other debt. This leads to the situation where investments in energy efficiency are attractive to the outside observer, but cannot pass the hurdle rates required by companies.	This discussion is not only for EE.	Neeraj Ramchandran	European Union (EU) - DG Research & Innovation	Belgium
70449	31	19	31	23	Technologies to convert low temperature waste heat to electricity usually have a low conversion efficiency of <10-20%. The upgrading and subsequent reuse of low temperature heat should have priority over the conversion of this heat into electricity. See also pg 30, lines 26-29.	Beyond this section.	Antoine BONDUELLE	European Union (EU) - DG Research & Innovation	Belgium
57383	31	25	35	1	For the electrification of industry, the section is missing two major recent peer-reviewed reports by ACEEE and GEI: - Hasanbeigi et al. 2021. Electrifying U.S. Industry Technology and Process-Based Approach to Decarbonization, https://www.globalefficiencyintel.com/electrifying-us-industry The report provides an analysis of the current state of industrial electrification needs, the technologies available, and the potential for electrification in thirteen industrial subsectors, separately in the U.S. It also discusses barriers, solutions, and an action plan for industrial electrification. - Rightor et al. 2020. Beneficial electrification in Industry, https://www.aceee.org/research-report/ie2002	I reviewed both the papers, and I am very familiar with Dr. Ali Hasanbeigi's excellent body of work as well as that of the ACEEE. The papers are grey literature that do not yet provide enough context for inclusion in Ch.11 (e.g. what is 134MT of total industry emissions in the US, and how applicable is this globally?). If refined, contectualized and placed in the peer reviewed literature I'm sure both bodies of work would be admissable for AR7.	Government of United States of America	U.S. Department of State	United States of America
2257	31	26	31	32	In order for electrification to become a major means of reducing greenhouse gases, it is premised that electricity is produced environmental-friendly. If the increasing electricity is produced with fossil fuels, it will not contribute significantly to the reduction of greenhouse gas emissions, and electrification will act as a factor that increases greenhouse gas emissions.	This is already addressed on page 32, lines 21-24. "The net GHG effect of electrification is contingent on how the electricity is made, and because total output increases can be expected for full effect it should be made with a very low or zero primary energy source (i.e. <50 grams CO2·kWh-1: e.g. hydroelectricity, nuclear energy, wind, solar photovoltaics, or fossil fuels with 95+% carbon capture and storage (Bruckner et al. 2014)). "	Government of United States of America	Hongik University	Republic of Korea
16557	31	26	31	32	In order for electrification to become a major means of reducing greenhouse gases, it is premised that electricity is produced environmental-friendly. If the increasing electricity is produced with fossil fuels, it will not contribute significantly to the reduction of greenhouse gas emissions, and electrification will act as a factor that increases greenhouse gas emissions.	This is already addressed on page 32, lines 21-24. "The net GHG effect of electrification is contingent on how the electricity is made, and because total output increases can be expected for full effect it should be made with a very low or zero primary energy source (i.e. <50 grams CO2·kWh-1: e.g. hydroelectricity, nuclear energy, wind, solar photovoltaics, or fossil fuels with 95+% carbon capture and storage (Bruckner et al. 2014)). "	Eric Masanet	Korea Meteorological Administration (KMA)	Republic of Korea
82757	31	29	31	32	there is also substantial opportunity in the manufacturing sector for switching to solar thermal, either for steam or hot water, which is ignored here but should at least be mentioned. See Schoeneberger et al. 2020 for a recent review and to identify some papers/numbers that can be cited	A section was added to 11.3.5 using the suggested reference.	Government of United States of America	Northwestern University	United States of America
57385	31	30	31	30	Do authors mean renewable electricity here?	This is addressed in the next sentence, and on Page 32, liens 21-24. It's not necessarily rernewable electricity, but ultra low GHG electricity. "The net GHG effect of electrification is contingent on how the electricity is made, and because total output increases can be expected for full effect it should be made with a very low or zero primary energy source (i.e. <50 grams CO2·kWh-1: e.g. hydroelectricity, nuclear energy, wind, solar photovoltaics, or fossil fuels with 95+% carbon capture and storage (Bruckner et al. 2014)). "	Government of United States of America	U.S. Department of State	United States of America
46119	31	31	31	31	Please consider that the oxidation of ammonia (e.g. in nitric acid and caprolactam production) leads to NOx including nitrous oxide N2O with a very high global warming potential as a by product (see e.g. UNFCCC National inventory reports, 2020, https://unfccc.int/ghg-inventories-annex-i-parties/2020 and The Nitric Acid Climate Action Group http://www.nitricacidaction.org/). The combustion of ammonia could lead to unacceptable NOx and maybe N2O and NH3 emissions, so there is a risk that switching to ammonia as a fuel could not be sustainable.	This sentence was added at the end of the ammonia section in 11.3.5. "If ammonia is used as a zero CO2 combustion fuel care must be taken to avoid N2O as a GHG and NOx in general as a local air pollutant. "	Government of Norway	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety International Climate Policy	Germany
84895	31	36	31	36	The point about CH4 leakage is extremely important. It can undermine the climate attributes of blue H2 entirely. This problem should get more focus and attention in the chapter.	This is already quite clear, but we have added references to very recent papers.	Antoine BONDUELLE	ClimateWorks Foundation	United States of America
72837	31	39	31	43	"dangerous strategy" could be developed in another sentence. The sentence is long (4 lines) with potential contradiction, maybe clear by fist stating the lock-in risk, then developing the trade-off in using "intermdiate energy" such as gas	The section was expanded and revised.	Government of Norway	EE-Consultant	France
3699	31	40			remove "the" before meet	Done.	Government of United States of America	Mines Saint-Etienne	France
57387	31	43			Many power generation plants and some industrial facilities have not only switched from coal to natural gas, but have also switched from conventional coal-fired boilers to gas turbines coupled with Heat Recovery Steam Generators. This has not only reduced emissions per mass of fuel input but has also dramatically reduced fuel input requirements for the same power (and thermal energy output for industrial plants). The fuel-to-power efficiency of the conventional coal-fired plants is nominally 35% and the fuel-to-power efficiency of the gas turbine HRSG combined cycle plants is nominally 50%, thus making the equipment switch economically attractive.	Agreed, text included to this effect.	Government of United States of America	U.S. Department of State	United States of America
43917	31	44	32	14	Wood pellets are commercial fuel that has a rapidly growing market. They are used for heating and electricity generation in various industrial sectors. I feel they should be mentioned and discussed in this section as it is a trend in many regions like Europe and southern U.S where many industries switch from fossil fuels to wood pellets, although there are some debates around the impacts of forest-based bioenergy on forest carbon stock, biodiversity, and overall climate benefits.	The essence of this is already included in the biofuel switching text.	Government of United States of America	Yale University	United States of America
63247	31	44	32	14	Solid biofuels are the most commonly used biofuels used in industry, mostly in forest industries (pulp and paper, sawmills). Their potential for fuel switching should be explicitely recognized, especially for process heat or steam production. Liquid biofuels are most likely to be used in transportation.	Text added in biofuel section.	Rebecca Dell	Environment and Climate Change Canada	Canada
82759	31	44	31	44	this paragraph implies that refined biofuels or biomethane are the main options, but there is also a large opportunity for direct combustion of solid biomass (e.g., in boilers or in cement kilns) that should be acknowledged, too. See IEA cement technology roadmap for some discussion of solid biomass in cement kilns, which is a large opportunity	Text added in biofuel section.	Cédric PHILIBERT	Northwestern University	United States of America
46121	32	3	32	14	The amount of biomass is limited and some, like straw, should rather be used as feedstocks for chemicals than as fuel. See our other comments on this issue.	Text changed to reflect limits on 1st & second gen biomass.	Eric Masanet	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety International Climate Policy	Germany
29041	32	11	32	14	Context? How does it compare against other fuels, what are the negative impacts of EVs?	The comment does not provide enough context to work with.	Government of Norway	IEAGHG	United Kingdom (of Great Britain and Northern Ireland)
29773	32	11	32	12	Please consider expanding on this issue, as more information could add value for policy makers. Most production routes for biofuels, biochemicals and biogas generate large side streams of concentrated CO2 which is easily captured, and which could become a source of BECCS unrelated to the actual combustion of the fuels or feedstocks (and without causing any additional trade-offs). CCS on the production of bioethanol is mentioned in chapter 11.3.6, page 11-35, line 26, as commercially available and cheap (USD10-40). Another source could be Sanchez, Johnsen et. al., 2018: "Near-term deployment of carbon capture and sequestration from biorefineries in the United States.", DOI 10.1073/pnas.1719695115. This is policy relevant because these point sources are often overlooked. Since emissions of bio-CO2 is considered carbon neutral many such sources are often neither reported in national statistics nor considered in climate policy frameworks.	Thank you for this reference, we have have used it to remove one sentence and add two.	Government of United States of America	Norwegian Environment Agency	Norway
31723	32	12	32	14	"Finally, it should be noted that biofuel combustion can potentially have substantial negative local air quality effects, with implications for SDG 3 and SDG 7"- SDG 11 (see target 11.6) can also be referred here	Done, thank you	Government of United States of America	Ahmedabad University	India
1203	32	13	32	13	between words "combustion" and "can" insert ", if inadequately controled,"	Done, thank you	Government of United States of America	Private Consultant	United States of America
63249	32	13	32	14	The combustion of any fuel can have negative local air quality effects. Combustion of biomass in industrial equipement with proper emissions control will meet regulatory requirements.	Text has been added to this point.	Christian Breyer	Environment and Climate Change Canada	Canada
70451	32	15	32	30	The use of (zero-emission) electricity in industrial processes virtually always has a higher efficiency than fuel-based strategies as combustion losses are eliminated. Besides, major steps in efficiency are possible when changing technologies eg from a gas-fired boiler for heat water to a heat pump or from a steam turbine to an electric motor. This increased efficiency has a cost benefit as well, often making electrification the cheapest option. Consider highlighting the increased efficiency of all-electric options compared to fuel-based options.	"end-use efficinecy" has been added.	Constantinos Psomopoulos	European Union (EU) - DG Research & Innovation	Belgium
70453	32	22	32	28	The conclusion that another energy carrier than electricity is required for temperatures of 1000°C-1700°C does not follow from the text before, where it is stated that "it has been demonstrated that almost any end use can be directly electrified". Consider highlighting the limited technology readiness of electrification for many of the current high temperature processes, suggesting to further increase technological development, switching to low temperature electrochemical processes where possible or using a chemical energy carrier instead.	Thank you for pointing this out, we were referring to the heat end uses. The text has been modified to highlight that the intantaneous thermal heat load for many sectors would require huge, likely unrealistic increases in electric capacity.	Miguel Angel Sanjuán	European Union (EU) - DG Research & Innovation	Belgium

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
57389	32	24	32	28	Authors might want to double-check statistics with NREL recent analysis [not public] related to potential of renewable energy penetration in the U.S. that requires, e.g., nuclear energy, fossil fuels with CCS, hydrogen fuel cells or turbines. Recent government modeling may offer different potential.	We can't use unpublished material. And we havent' seen sources that show above 60-70% wind and solar that don't have firm power support - which could be self made hydrogen or other renewables. We have added Williams et al 2021	Aniceto Zaragoza	U.S. Department of State	United States of America
84189	32	24	32	28	Current text: "This has strong implications for the electricity sector and its generation mix; despite their low and falling costs, above 60-70% progressively higher mixes of variable wind and solar on a given grid will require a firm low or zero emissions generation source (e.g. nuclear energy, fossil fuels with CCS, hydrogen fuel cells or turbines) to moderate costs (Jenkins et al. 2018; Sepulveda et al. 2018)." I suggest to modify the text in this way: "This has strong implications for the electricity sector and its generation mix; despite their low and falling costs, above 60-70% progressively higher mixes of variable wind and solar on a given grid will require a firm low or zero emissions generation source (e.g. nuclear energy, fossil fuels with CCS, hydrogen fuel cells or turbines) to moderate costs (Jenkins et al. 2018; Sepulveda et al. 2018; Romeri 2019)." Rationale: In recent years I published different papers with regard of possible use of hydrogen fuel cells as electric generation plant. In particular, in my studies I assessed the economic possibility (in LCOE terms, in hypothesis of fuel cell vehicles mass production) to use an Hydrogen Fuel Cells Powertrain as Power Generation Plant obtaining surprisingly and positive results. In my analysis the economic advantage 'to consider an H2FCPowertrain as power generation plant' and related possible long-term effects in power generation are confirmed year after year. In my analysis I found that the adoption of Hydrogen Fuel Cells Powertrain as Power Generation Plant could have relevant long-term effects in the power generation sector. In my 2019 study I wrote: "As I underlined in my 2018 study: "Thanks to the introduction and use of H2FCPowertrains as power plants, considering the low level of Overnight Cost, it seem to be possible to think that the present capital intensive profile of the Power Generation Sector could change gradually. In terms of plant Lifetime, the H2FCPowertrain appears poor (also considering the DOE target of 8000 hours lifetime) if compared either to the other generation technologies or to the U.S. DOE CHP target (80000 hours). But, in a long term investment perspective, it is possible to foresee a planned replacement of the H2FCPowertrain stack at the end of each lifetime at a cost that is estimated around 42% of the whole system (and this, without taking into account the value of recoverable Platinum from the exhaust stack). Thanks to the introduction and use of H2FCPowertrains as power plants it seems to be possible also to think that the present long-term investment profile of the Power Generation Sector could change gradually". These disruptive long-term possible effects are confirmed in the present analysis." This solution, if rapidly adopted at scale level, seems to be able to give a contribution to the climate emergency challenge. However, this low-carbon solution has still not been considered in international energy and climate change debate. So I suggest to consider and to mention also this perspective in the final version of this SOD draft. References: 2015 – M.V. Romeri "Hydrogen and Fuel Cell: A Cinderella or a Disruptive Low-Carbon Solution?" at "2015 Fuel Cell Seminar & Energy Exposition", Los Angeles CA, USA [Available at ECST: <http://ecst.ecsdl.org/content/71/1/227> or <http://dx.doi.org/10.1149/07101.0227ecst >]; 2017 – M.V. Romeri "Considering Hydrogen Fuel Cells Powertrain as Power Generation Plant – 2017 review" (published January 2018) in "2nd AIEE Energy Symposium Conference Proceedings", Rome, Lumsa University [Available at: <http://www.aieeconference2017rome.eu/documents/Rome-Proceedings.pdf >]; 2018 – M.V. Romeri "Consideration about Hydrogen and Fuel Cells in the Paris Agreement 1.5°C Perspective" (published January 2019) in "3rd AIEE Energy Symposium Conference Proceedings", Milan, Bocconi University [Available at: <http://www.aieeconference2018milan.eu/documents/AIEE_SYMPOSIUM_2018_proceedings.pdf>]; 2019 – M.V. Romeri "The history could repeat itself: hydrogen-oxygen fuel cell is the 'game changer'" (published December 2019-January 2020) in "4th AIEE Energy Symposium Conference Proceedings" Rome, Lumsa University [Available at: <http://www.aieeconference2019rome.eu/documents/AIEE_Symposium_Proceedings_4.pdf >]; 2020 – M.V. Romeri presentation "Hydrogen and fuel cell: looking back to 20 year of professional experience and looking forward beyond 'Covid-19' and toward '1.5° C Perspective'" (presented December 2020) at "5th AIEE Energy Symposium" Virtual conference, Milan, SDA Bocconi School of Management [available at <https://www.aieesymposium.eu/wp-content/uploads/2020/12/ROMERI-.pdf>].	While I recognize the author may hav contributed something, conference proceedings are normally not peer reviewed, and we are only adding exceptional peer reviewed literature at this state in the review cycle.	PEDRO MORA PERIS	Independent consultant	Italy
57391	32	26	32	28	Can increased storage also play a role here?	Text modified.	NAOKI AOKI	U.S. Department of State	United States of America
82761	32	31	32	40	consider using and citing data from the U.S. industrial electrification scenarios here: https://www.nrel.gov/docs/fy18osti/71500.pdf'	We reviewed the report; while the transport portion and to a certain extent the buildings sections are well develop, the industrial electrification portion was less developed than other studies for industry. We have added a reference.	Aniceto Zaragoza	Northwestern University	United States of America
82763	32	31	32	31	of these options, it seems worth highlighting that electric boilers (including newer electrode boilers with high capacity) are truly a drop-in solution that doesn't require any process-level reengineering like would be needed to switch to electric curing, drying, resistance heating, etc. as such, eboilers represent a truly drop-in and cross-cutting means of rapid electrification that can't be said of the others in the same sentence	This is already addressed.	Richard Bohan	Northwestern University	United States of America
84897	32	31	32	34	This sentence does not seem consistent with the content in section 11.3.4	Point taken - we have done some reorganization of the text based on this.	Miguel Angel Sanjuán	ClimateWorks Foundation	United States of America
57393	32	35	32	40	The sentence below seems to be more of an introduction or overview to the issues about industrial electrification, but it is stuck at the end of a paragraph on steam boilers, curing, etc. Shouldn't it be above in the first paragraph on industrial electrification? Industrial electrification is most viable in the near term: with minimal retrofitting and rebuild in processes; with relatively low energy costs; where the degree of process complexity and process integration is more limited and extensive process re-engineering would not be required; where combined heat and power is not used; where induction heating technologies are viable; and where process heating temperatures are lower (Deason et al., 2018).	Point taken - we have done some reorganization of the text based on this.	PEDRO MORA PERIS	U.S. Department of State	United States of America
57395	32	41	32	46	Also consider the following paper published in January 2021, which outlines electrification potential for many of the energy intensive industries: Electrifying U.S. Industry: A Technology- and Process-Based Approach to Decarbonization https://www.renewablethermal.org/electrifying-us-industry/	Will review for inclusion if time allows. However, only limited and crucial grey literature is being added at this point.	Eric Masanet	U.S. Department of State	United States of America
57397	33	3	33	3	Does electrifying cement calcination have any effect on cement process emissions?	No.	Miguel Angel Sanjuán	U.S. Department of State	United States of America
47267	33	4	33	21	Core message of this section seems obscured with citations of absolute values - could more clearly focus on the ratio between single sector electricity demand , versus maximally assumed available clean electricity in broader system studies.	We thoguht about this, and we are happy with the section as is.	Eric Masanet	PBL Netherlands Environmental Assessme	Netherlands
15865	33	4	33	7	a conjuncton might be needed	Reviwed and modified.	Richard Bohan	KIET(KOREA INSTITUTE FOR INDUSTRIAL E	Republic of Korea
82765	33	4	33	7	this sentence was hard to follow; reword for clarity?	Reviwed and modified.	Government of Saudi Arabia	Northwestern University	United States of America
57399	33	4	33	4	"more supply of electricity" is stilted. Perhaps this would be better as: "Increased electrification of industry will result in increased overall demand for electricity."	Reviwed and modified.	Government of Norway	U.S. Department of State	United States of America
72839	33	4	33	21	This paragraph is interesting but could be clarified between existing consumptions and future projections. Notably line 6 "increased demand" (past?) seem to apply to a future. Same problem line 11 "rose" seem to apply to a future demand.	Reviwed and modified.	Government of United States of America	EE-Consultant	France
84899	33	4	33	21	It would be more helpful to quantify the increased electricity demand in terms of total energy, for example saying the steel industry is using X GJ of all types of energy of which Y% is electricity, and under an electrification scenario it would be A GJ of which B% is electricity.	Reviwed and modified.	Richard Bohan	ClimateWorks Foundation	United States of America
15867	33	7	33	7	parentheses for Vogl et al. 2018a should be removed.	Reviwed and modified.	Aniceto Zaragoza	KIET(KOREA INSTITUTE FOR INDUSTRIAL E	Republic of Korea
47265	33	7	33	7	"these values are consisten with" - previous sentence does not cite the source of the values. Is it Material Economics?	Reviwed and modified.	PEDRO MORA PERIS	PBL Netherlands Environmental Assessme	Netherlands
57401	33	11	33	11	"from 118 TWh to 510, 395 and 413 TWh" is unclear. To what do the three values (510, 395, and 413 TWh) refer? Are these for different processes, different time periods, etc.?	Reviwed and modified.	Miguel Angel Sanjuán	U.S. Department of State	United States of America
57403	33	14	33	21	Renewable supply needs fossil or battery backup. But think of the implications of switching to a renewable supply (much of which is available only during the day) on heat intensive industries, many of which need to run 24/7 for economic reasons. The amount of fossil or battery backup necessary will be larger than other sectors.	See earlier text in 11.3.5 on grid flexibility and firm power needs.	Aniceto Zaragoza	U.S. Department of State	United States of America
69863	33	22	33	28	It seems somewhat contradictory to state that any end use can be directly electrified, then mention the "need" for another energy carrier. I would more cautiously mention the "possibility" that other energy carriers prove more adapted to some tasks.	Paragprah modified for clarification on instantaneous capacity needs.	PEDRO MORA PERIS	Institut Français des Relations Internationales	France
57405	33	26	33	27	"already discussed" appears 2x and isn't needed in either case. Delete.	Removed	JAE YOON LEE	U.S. Department of State	United States of America
57407	33	29	33	29	Recommend moving the text in the next paragraph up before this paragraph (switching the paragraph that begins "Broadly speaking" with the paragraph that begins "Around 70 Mt") since the second paragraph introduces the concept and the first provides more detail.	Done, thank you	Miguel Angel Sanjuán	U.S. Department of State	United States of America
57409	33	29	33	29	"on purpose" is not needed. Delete.	Done, thank you	Aniceto Zaragoza	U.S. Department of State	United States of America
84901	33	29	33	39	Several of the numbers in this paragraph appear to be uncited	Reference added.	PEDRO MORA PERIS	ClimateWorks Foundation	United States of America
57411	33	30	33	30	Should be: "resulting in emissions of roughly 830 ..."	Fixed.	Aniceto Zaragoza	U.S. Department of State	United States of America
2373	33	31	33	33	"Fuels refining (~410MtCO2 yr-1) and production of ammonia (420 MtCO2·yr-1) largely dominate its uses" : this adds to 830 Mt CO2 or the full CO2 from H2- is this correct?	Yes.	PEDRO MORA PERIS	Lawrence Berkeley Lab	United States of America
77625	33	36	33	37	Steam reforming H2 production with CCS is known as "blue hydrogen"	Added.	Richard Bohan	Climate Wedge LLC	United States of America
70455	33	40	34	3	Consider adding that hydrogen solutions have a lower efficiency than direct electrification in many use cases (low and high temperature heat, road transport), so electrification should be the preferred option where possible, practical and economical. A core point in the chapter for industry is to strive for a higher energy efficiency, this recommendation would be very much in line with that message.	This point is made in the summary, and we have added "end-use efficiency" to 11.3.5	Miguel Angel Sanjuán	European Union (EU) - DG Research & Innovation	Belgium
74239	33	40	34	3	These paragraphs should be revised so that they are not renewables centric. Green hydrogen produced by carbon free nuclear is exactly the same as hydrogen produced by renewables. The point is to manufacture hydrogen using carbon free energy. Additionally, due to its energy density, nuclear and can produce significantly more hydrogen with a smaller geographical footprint.	Nucelar has been added as an electrothermal hydrogen source.	Miguel Angel Sanjuán	Pillsbury Law Firm	United States of America
69865	33	47	33	47	As it contains not only hydrogen and carbon, but also oxygen, methanol is not considered a hydrocarbon, but an alcohol	Fixed, thanks for the reminder.	Aniceto Zaragoza	Institut Français des Relations	France
47269	34	1	34	1	If the term "Hard to abate" is to be contested, it may be sensible to refrain from using the term in this chapter all together. It could be just as effective to state that hydrogen can substitute fossil fuel uses in industry, aviation and shipping.	Changed.	PEDRO MORA PERIS	PBL Netherlands Environmental Assessme	Netherlands
47271	34	7	34	8	Sentence is unclear.	Fixed, thanks for pointing this out.	Government of Norway	PBL Netherlands Environmental Assessme	Netherlands
57413	34	7	34	8	Reword: "Ammonia has been historically made using hydrogen that has been generated using electrolysis, and could be again using renewable electricity."	Fixed, thanks for pointing this out.	Government of United States of America	U.S. Department of State	United States of America
47273	34	9	34	9	The use of "net-zero" synthetic hydrocarbon is confusing here - it is better to explain the different sources for the C element, before concluding the labels synthetic hydrocarbons could have. The paragraph on page 36 (L32-L40) states a similar message but is written in a much more considerate fashion. Also wouldn't biogenic C + green H2 lead to a carbon-neutral product instead?	This is disucssed in 11.3.6	Eric Masanet	PBL Netherlands Environmental Assessme	Netherlands

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
60481	34	9	34	18	The first sentence should be: Hydrogen, together with CO2, can produce alternative fuels via the power-to-fuel approach. A large number of CO2-based fuels/e-fuels can been produced, such as methane, methanol and other potential.....Line 12-18 : Following the CCU concept, CO2 can be captured at point sources or directly from the atmosphere and subsequently converted into valuable products such as building materials, chemicals, synthetic fuels (e.g. Styring et al., 2011; von der Assen et al., 2013, SAPEA, 2018, Kätelhön et al., 2019, Ramboll 2019, Wich et al., 2020). The duration of the CO2 storage into a product strongly varies from days to millenia according to the applications. However, in term of environmental assessment, CCU technologies should not be assessed only with respect to the amounts of CO2 that can be used nor to its storage duration, but rather it is essential to determine the life cycle of the CO2-based product generated (e.g. Bruhn et al., 2016, Zimmerman et al., 2018, Nocito and DiBenedetto al., 2020). If these products are assumed to be substitutes for fossil-based products and thus provide the same service (i.e. it would be used and disposed of according to the same patterns as conventional products), the focus of the life-cycle-analysis may lie in the cradle-to-gate phase (e.g. Kätelhön, et al., 2019). Two important points should however be highlighted (Arning et al., 2019, IEAGHG, 2019a.b, 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 : •Ramboll, 2019, The Institute for Advanced Sustainability Studies CESR, CEDelft and IOM Law.•Wich et al. 2020, Frontiers Energy Research, 7, 162.•SAPEA, 2018, Science Advice for Policy by EU Academies, Novel Carbon Capture and Utilisation Technologies-Research and Climate Aspects, Evidence Review Report, 2.•Zimmerman et al., 2018 , CO2 Chem Media and Publishing Ltd.•Styring et al., 2011, Carbon Capture and Utilization in the Green Economy. Centre for Low Carbon Futures, York.•Von der Assen et al., 2013, Energy Environ. Sci. 6, 2721–2734.•Zhu, 2019, Clean Energy, Vol. 3, No. 2, 85–100.•Kätelhön et al., 2019, PNAS, 116, 23, 11187-11194.•Bruhn et al., 2016, Environmental Science & Policy, 60, 38–43.•IEAGHG, 2019a: Putting CO2 to Use – Creating value from emissions, International Energy Agency. •IEAGHG, 2019b: Exploring Clean Energy Pathways: the role of energy storage, International Energy Agency.•Nocito and Dibenedetto, 2020, Current Opinion in Green and Sustainable Chemistry, 21, 34–43. •Wich et al. 2020, Frontiers Energy Research, 7, 162.•Nocito and Dibenedetto, 2020, Current Opinion in Green and Sustainable Chemistry, 21, 34–43.	E-fuels & power to x are a specific class of lower carbon fuels, and this has been edited into 11.3.6	Eric Masanet	Université Libre de Bruxelles / CO2 Value Europe	Belgium
83725	34	9	34	18	The first sentence should be: Hydrogen, together with CO2, can produce alternative fuels via the power-to-fuel approach. A large number of CO2-based fuels/e-fuels can been produced, such as methane, methanol and other potential.....Line 12-18 : Following the CCU concept, CO2 can be captured at point sources or directly from the atmosphere and subsequently converted into valuable products such as building materials, chemicals, synthetic fuels (e.g. Styring et al., 2011; von der Assen et al., 2013, SAPEA, 2018, Kätelhön et al., 2019, Ramboll 2019, Wich et al., 2020). The duration of the CO2 storage into a product strongly varies from days to millenia according to the applications. However, in term of environmental assessment, CCU technologies should not be assessed only with respect to the amounts of CO2 that can be used nor to its storage duration, but rather it is essential to determine the life cycle of the CO2-based product generated (e.g. Bruhn et al., 2016, Zimmerman et al., 2018, Nocito and DiBenedetto al., 2020). If these products are assumed to be substitutes for fossil-based products and thus provide the same service (i.e. it would be used and disposed of according to the same patterns as conventional products), the focus of the life-cycle-analysis may lie in the cradle-to-gate phase (e.g. Kätelhön, et al., 2019). Two important points should however be highlighted (Arning et al., 2019, IEAGHG, 2019a.b, 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 : •Ramboll, 2019, The Institute for Advanced Sustainability Studies CESR, CEDelft and IOM Law.•Wich et al. 2020, Frontiers Energy Research, 7, 162.•SAPEA, 2018, Science Advice for Policy by EU Academies, Novel Carbon Capture and Utilisation Technologies-Research and Climate Aspects, Evidence Review Report, 2.•Zimmerman et al., 2018 , CO2 Chem Media and Publishing Ltd.•Styring et al., 2011, Carbon Capture and Utilization in the Green Economy. Centre for Low Carbon Futures, York.•Von der Assen et al., 2013, Energy Environ. Sci. 6, 2721–2734.•Zhu, 2019, Clean Energy, Vol. 3, No. 2, 85–100.•Kätelhön et al., 2019, PNAS, 116, 23, 11187-11194.•Bruhn et al., 2016, Environmental Science & Policy, 60, 38–43.•IEAGHG, 2019a: Putting CO2 to Use – Creating value from emissions, International Energy Agency. •IEAGHG, 2019b: Exploring Clean Energy Pathways: the role of energy storage, International Energy Agency.•Nocito and Dibenedetto, 2020, Current Opinion in Green and Sustainable Chemistry, 21, 34–43. •Wich et al. 2020, Frontiers Energy Research, 7, 162.•Nocito and Dibenedetto, 2020, Current Opinion in Green and Sustainable Chemistry, 21, 34–43.	E-fuels & power to x are a specific class of lower carbon fuels, and this has been edited into 11.3.6	Government of Norway	LUT University	Finland
57415	34	20	34	43	Why is this information in a box and not included in the main text?	Because we were asked to, to highlight hydrogne's newness	Rebecca Dell	U.S. Department of State	United States of America
84905	34	24			I was confused by the reference to "small scale decentralized cogeneration". Also your timeline for HYBRIT appears to be out of date (2024, not 2026)	Hybrit fixed.	Rebecca Dell	ClimateWorks Foundation	United States of America
2375	34	25	34	25	Suggest stating in this box that most H2 is generated from fossil fuel sources today and results in CO2 emissions.	Done.	Government of Norway	Lawrence Berkeley Lab	United States of America
24695	34	37	34	39	Hydrogen produced via electrolysis: both renewable and nuclear power can be used in this process (see reference already used in the chapter: Bicer, Y., and Dincer, I. (2017). Life cycle assessment of nuclear-based hydrogen and ammonia production options: A comparative evaluation. International Journal of Hydrogen Energy, 42(33), 21559–21570. https://doi.org/https://doi.org/10.1016/j.ijhydene.2017.02.002). We therefore recommend inserting a sentence to highlight that nuclear could offer a potential solution as the location of NPPs is not dependent on weather conditions nor suitable geology for CCS storage (and so it would reduce the need for industries to relocate to these regions)	Added.	Richard Bohan	FORATOM (European Atomic Forum)	Belgium
74241	34	37	34	43	This paragraph should be revised so that it is not renewables centric. Green hydrogen produced by carbon free nuclear is exactly the same as hydrogen produced by renewables. The point is to manufacture hydrogen using carbon free energy. Additionally, due to its energy density, nuclear can produce significantly more hydrogen with a smaller geographical footprint.	Point taken and revised.	Eric Masanet	Pillsbury Law Firm	United States of America
84907	35	1	37	30	This section was particularly poorly written and difficult to understand. It included numerous terms that most readers would not know and were never defined, like "acid gas injection".	Rewritten.	Richard Bohan	ClimateWorks Foundation	United States of America
82769	35	1	35	1	Regarding CCU, this section should at least briefly mention CO2 curing in concrete and utilization of alkaline materials (industrial wastes or naturally occuring) for mineralization to concrete aggregates. See for example https://doi.org/10.1038/s41893-020-0486-9. However, some alkaline wastes can be used directly as SCMs to reduce clinker-to-cement ratios, so there is competition between levers	Thanks, this is also discussed in 11.4 in relation to cement and 1.2.2 and 11.3.6	Edgar Hertwich	Northwestern University	United States of America
81895	35	6	35	6	Since the definition of CCU which can commonly be found in the current literature concerns the capture and utilization of just CO2 and not of CO, it would be adequate to address this nomenclature issue in this secion.	No - it applies to both. CO oxidizes to CO2 in the atmosphre.	Mariel Vilella	Université de Lausanne	Switzerland
81893	35	8	35	8	"released to atmosphere" --> "released to the atmosphere", or "released into the atmosphere"	Done	Government of Germany	Université de Lausanne	Switzerland
57417	35	17	35	17	Regarding the phrase "all not considering the energy used to drive the above processes", can authors discuss and quantify if possible the amount of energy use for these processes? This is an important consideration.	This is covered in pervious CCU & CCS work and Chapter 6. We have limited space.	NAOKI AOKI	U.S. Department of State	United States of America
82767	35	19	35	20	for current CCS cost data, consider citing IEA ETP2020 and/or https://www.iea.org/reports/ccus-in-clean-energy-transitions	Done, with Kearns et al 20201 added	Mariel Vilella	Northwestern University	United States of America
29775	35	21	35	24	Please consider rephrasing this sentence to include the option of partial biomass use. For example: "As a general rule it is not possible to capture all the carbon dioxide emissions from an industrial plant. To achieve zero or negative emissions, CCS would need to be combined with some use of sustainably sourced biofuel or -feedstock, or the remaining emissions would need to be offset by CDR elsewhere". A 90 % capture rate would imply that if 10 % of the fuel/feedstock is biogenic, net emissions would be zero. A higher input of biomass would lead to negative emissions. Several Norwegian companies are pursuing such concepts, including in cement, non-ferrous metals, chemicals and refining. In a recently publicised roadmap for the Norwegian heavy industry the industry sector becomes a net sink by 2050 in this way.	Fully accepted, thank you.	Eric Masanet	Norwegian Environment Agency	Norway
2377	35	28	35	28	I'm not sure what "already amenable to commercial oil and gas techniques for acid gas injection" is referring to and suggest that this is rewritten for clarity and simplification such as Concentrated CO2 sources such as A and B are most amenable to economic carbon capture and subsequent use by the oil and gas inudstry for C."	Done.	Cédric PHILIBERT	Lawrence Berkeley Lab	United States of America
17833	35	32	35	34	Sentence "Unfortunately, concentrated process CO2 emissions are often exempted from existing cap and trade systems, and these opportunities for CCS have largely gone unexploited." does not seem correct. The largest emissions trading system, the EU ETS, does cover concentrated process CO2 emissions, for example large scale hydrogen production is included.	Done	Eric Masanet	Global CCS Institute	Belgium
57419	35	32	35	32	"Unfortunately" seems like a value judgement and should be removed. Re-write as: "Since concentrated process CO2 emissions are often exempted from existing cap and trade systems, these opportunities for CCS have largely gone unexploited."	Done, thank you.	Christian Breyer	U.S. Department of State	United States of America
17867	35	34	35	36	"relatively permanent nature of the CO2 disposal" adds some unnecessary uncertainty. Where formally monitored as requires, there is certainty.	Fixed.	Government of United States of America	Global CCS Institute	Belgium
29435	35	47	36	2	Consider adding information of the Longship project enabling a flexible ship-based CO2 transport system enabling of a multiple source - single sink system for Europe. The transport and storage part of Longship is called Northern Light, a consortium of Equinor, Total and Shell. The project have passed the final investment decision in 2020 and will be in operation in 2024. (Source: https://www.regjeringen.no/contentassets/943cb244091d4b2fb3782f395d69b05b/en-gb/pdfs/stm201920200033000engpdfs.pdf)	This is too specific to one region, and to a given time and project (that could get cancelled).	Government of Germany	Norwegian Environment Agency	Norway

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
60483	36	3	37	30	In this quite exhaustive discussion on CCU, one important point is missing, it is the role of CO2 mineralisation to create building material and storing CO2 permanently in them. It allows net zero emission reduction, but also negative emissions, in the case CO2 is captured directly from the atmosphere. Carbon mineralization is an emerging approach to remove CO2 from the air and/or store it under the form of carbonate minerals into building materials. Originally, mineralization is a natural process occuring on geological time-scale during the weathering of silicate materials and rocks rich in Ca and Mg, coming from the Earth's upper mantle. Because it utilises this naturally available chemical energy, this method may offer a low cost means to mitigate greenhouse gas emissions and lock CO2 into solid carbonate minerals, in a permanent and nontoxic way (e.g.Zevenhoven and Fagerlund, 2010, Giannoulakis et al., 2014, Cuéllar-Franca et Azapagic, 2015, Kaliyavaradhan et al., 2017, NAS, 2019, Huang et al., 2019, Lee et al., 2020, Pan et al., 2020). The conversion of CO2 into carbonates may offer a potential to convert low value materials into useful products, namely concrete, asphalt and construction fill." (SAM, 2018)A promising pathway is to let CO2 react with mineral- rich industrial wastes (e.g. concrete debris) to create new building material.This circular concept allows to decrease CO2 emissions and landfills, but also to sequested CO2 permanently in valuable products (e.g. Ebrahimi et al., 2017, Pasquier et al., 2018, Zhang et al., 2020, Tripathi et al., 2020). Moreover, mineralisation of CO2 into cementitious materials improves upon material quality by densifying and reducing water absorption of such materials whilst permanently imprisoning CO2 (Tam et al., 2020) Ostovari et al., 2020 have shown that all considered CCU technologies for mineralization could reduce climate impacts over the entire life cycle based on the current state-of-the-art and today's energy mix. Reductions range from 0.44 to 1.17 ton CO2e per ton CO2 stored. For all mineralisation pathways evaluated, the carbon footprint is mainly reduced due to the permanent storage of CO2 and the credit for substituting conventional products. Thus, developing suitable products is critical to realize the potential benefits in practice. Then, carbon capture and utilization by mineralization could provide a promising route for climate change mitigation. Current data suggests that up to 1 Gt per year of the cement market could be substituted by mineralization products. Di Maria et al., 2020 conducted an LCA of carbonated steel slag including CO2 capture and confirm that mineralization 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. The manufacture of carbonated aggregates starts to be commercially established at global scale, and recent advances in technology include a mobile plant that directly utilizes flue-gas derived CO2 in the mineralisation process in the UK (Hills et al., 2020). At mid-term, direct air capture combined with CO2 mineralisation could allow creating negative emissions as CO2 will be removed from the atmosphere and store permanently in materials (e.g. SAPEA, 2018, Beuttler et al., 2019, Breyer et al., 2019).•Giannoulakis et al., 2014, International Journal of GHG Control, 21, 140-157.•Beuttler et al., 2019, Frontiers n Climate, 1 :10.•Breyer et al., 2019, Joule, 3, 2053-2057.•Di Maria et al, 2020, International Journal of Greenhouse Gas Control, 93.•Ebrahimi et al., 2017, J. of Cleaner Production, 156, 660-669.•Cuéllar-Franca and Azapagic, 2015, J.CO2.Utili., 9, 82-102.•Huang et al., 2019, J. of Cleaner Production, 241, 118359.•Lee et al., 2020, J. CO2. Util., 37, 113-121.•NAS, 2019, Negative Emissions Technologies and Reliable Sequestration, The National Academies Press. •Ostovari et al., 2020, Sustainable Energy Fuels, 4, 4482-4496. •Pan et al., 2020, Nature Scientific Reports 7, 17227.•Tripathi et al., 2020, Nature Scientific Report, 10:958.•Zhang et al., 2020, Renewable and Sustainable Energy Reviews, 117, 109495.•Zevenhoven and J . Fagerlund, 2010, Mineralisation of carbon dioxide (CO2), 433-462, 16, Åbo Akademi University, Finland, Woodhead Publishing Limited.•Tam et al., 2020, Construction and building Materials, 250, 118903. •Zimmerman et al., 2018 , CO2 Chem Media and Publishing Ltd.•Pasquier et al., 2018, Geosciences, 8(9), 342.•Kaliyavaradhan et al., 2017, J. CO2. Utili., 20, 234-242.	Reviwed, paragraph added using some of the references.	Government of Germany	Université Libre de Bruxelles / CO2 Value Europe	Belgium
83727	36	3	37	30	In this quite exhaustive discussion on CCU, one important point is missing, it is the role of CO2 mineralisation to create building material and storing CO2 permanently in them. It allows net zero emission reduction, but also negative emissions, in the case CO2 is captured directly from the atmosphere. Carbon mineralization is an emerging approach to remove CO2 from the air and/or store it under the form of carbonate minerals into building materials. Originally, mineralization is a natural process occuring on geological time-scale during the weathering of silicate materials and rocks rich in Ca and Mg, coming from the Earth's upper mantle. Because it utilises this naturally available chemical energy, this method may offer a low cost means to mitigate greenhouse gas emissions and lock CO2 into solid carbonate minerals, in a permanent and nontoxic way (e.g.Zevenhoven and Fagerlund, 2010, Giannoulakis et al., 2014, Cuéllar-Franca et Azapagic, 2015, Kaliyavaradhan et al., 2017, NAS, 2019, Huang et al., 2019, Lee et al., 2020, Pan et al., 2020). The conversion of CO2 into carbonates may offer a potential to convert low value materials into useful products, namely concrete, asphalt and construction fill." (SAM, 2018)A promising pathway is to let CO2 react with mineral- rich industrial wastes (e.g. concrete debris) to create new building material.This circular concept allows to decrease CO2 emissions and landfills, but also to sequested CO2 permanently in valuable products (e.g. Ebrahimi et al., 2017, Pasquier et al., 2018, Zhang et al., 2020, Tripathi et al., 2020). Moreover, mineralisation of CO2 into cementitious materials improves upon material quality by densifying and reducing water absorption of such materials whilst permanently imprisoning CO2 (Tam et al., 2020) Ostovari et al., 2020 have shown that all considered CCU technologies for mineralization could reduce climate impacts over the entire life cycle based on the current state-of-the-art and today's energy mix. Reductions range from 0.44 to 1.17 ton CO2e per ton CO2 stored. For all mineralisation pathways evaluated, the carbon footprint is mainly reduced due to the permanent storage of CO2 and the credit for substituting conventional products. Thus, developing suitable products is critical to realize the potential benefits in practice. Then, carbon capture and utilization by mineralization could provide a promising route for climate change mitigation. Current data suggests that up to 1 Gt per year of the cement market could be substituted by mineralization products. Di Maria et al., 2020 conducted an LCA of carbonated steel slag including CO2 capture and confirm that mineralization 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. The manufacture of carbonated aggregates starts to be commercially established at global scale, and recent advances in technology include a mobile plant that directly utilizes flue-gas derived CO2 in the mineralisation process in the UK (Hills et al., 2020). At mid-term, direct air capture combined with CO2 mineralisation could allow creating negative emissions as CO2 will be removed from the atmosphere and store permanently in materials (e.g. SAPEA, 2018, Beuttler et al., 2019, Breyer et al., 2019).•Giannoulakis et al., 2014, International Journal of GHG Control, 21, 140-157.•Beuttler et al., 2019, Frontiers n Climate, 1 :10.•Breyer et al., 2019, Joule, 3, 2053-2057.•Di Maria et al, 2020, International Journal of Greenhouse Gas Control, 93.•Ebrahimi et al., 2017, J. of Cleaner Production, 156, 660-669.•Cuéllar-Franca and Azapagic, 2015, J.CO2.Utili., 9, 82-102.•Huang et al., 2019, J. of Cleaner Production, 241, 118359.•Lee et al., 2020, J. CO2. Util., 37, 113-121.•NAS, 2019, Negative Emissions Technologies and Reliable Sequestration, The National Academies Press. •Ostovari et al., 2020, Sustainable Energy Fuels, 4, 4482-4496. •Pan et al., 2020, Nature Scientific Reports 7, 17227.•Tripathi et al., 2020, Nature Scientific Report, 10:958.•Zhang et al., 2020, Renewable and Sustainable Energy Reviews, 117, 109495.•Zevenhoven and J . Fagerlund, 2010, Mineralisation of carbon dioxide (CO2), 433-462, 16, Åbo Akademi University, Finland, Woodhead Publishing Limited.•Tam et al., 2020, Construction and building Materials, 250, 118903. •Zimmerman et al., 2018 , CO2 Chem Media and Publishing Ltd.•Pasquier et al., 2018, Geosciences, 8(9), 342.•Kaliyavaradhan et al., 2017, J. CO2. Utili., 20, 234-242.	See previous comment. Also the word limit prevents us from delving too deep into this particular topic.	Government of Germany	LUT University	Finland
43915	36	13	36	16	In this sentence, statement that "the net GHG mitigation impact.... has to be determined by life cycle cost anlaysis" does not make sense. Life cycle cost analysis (LCC) focuses on cost, its outputs are in the unit of currency not how much GHG can be mitigated (such information may be needed as inputs of LCC, but not outputs). Evaluating the net GHG mitigation potential across the life-cycle can be evaluated by LCA or life cycle carbon analysis, process models, but definitely not LCC alone. Even with cost analysis, more literature use Techno-Economic Analysis (TEA) than LCC. I also checked the two references listed here:Bruhn et al. (2016); Nocito and Dibenedetto (2020). None of these two studies mention about LCC? Here is a literature that examined the cost and net GHG migitation potential and costs of carbon capture applied to oil refineries using bottom-up process models and TEA:, Quantifying carbon capture potential and cost of carbon capture technology application in the U.S. refining industry, International Journal of Greenhouse Gas Control, Volume 74,2018, 87-98,https://doi.org/10.1016/j.ijggc.2018.04.020.	This was an editing error - cost should have been CO2 or GHG	Government of United States of America	Yale University	United States of America
7841	36	19	37	22	The concept of CCU is rather new and readers would like to know the effectiveness of emission reductions of CCU. In lines 19-20 in page 36, it is explained that "if only recycled once and then emitted, the maximum reduction is 50%". Whereas, in page 37 lines 21-22, the text says that "it is unlikely the chemical conversion of CO2 for CCU will account for more than 1% of overall mitigation". It will be useful for policy makers if this chapter provide information to what extent emissions will be reduced by CCU in industry sector. Just for your information, there is a following description on page 25 lines 10-11 in WG3 Chapter 12: "Utilisation of captured CO2 (DACCU) (Breyer et al. 2019b) to produce synthetic fuels, building materials or plastics may not have a long-term removal effect, depending on the lifetime of respective products."	Thank you, we have taken this into consideration during editing.	Government of United States of America	Research Institute for the Innovative Technology for the Earth (RITE)	Japan
2379	36	19	36	19	"If only recycled once" : this is not clear: what is being recycled?	Edited	Cécile Seguineaud	Lawrence Berkeley Lab	United States of America
84909	36	20			Why does a single carbon recycling step have a maximum emissions reduction of 50%?	Edited	Government of United States of America	ClimateWorks Foundation	United States of America
43913	36	23	36	23	I think those are mostly caused by different system boundaries and counterfactural scenarios defined by those LCAs rather than the "complexity of the life cycle analysis accounting" in this sentence?	Noted	Cécile Seguineaud	Yale University	United States of America
5529	36	28	36	28	replace Renewables" by "low carbon sources"	Corrected	Government of Germany	Retraité/ Pdt d'association	France
3701	36	28	36	29	point of view	Corrected	Government of Canada	Mines Saint-Etienne	France
72841	36	28	36	29	point "of" view ? Suing?	Corrected	Government of United States of America	EE-Consultant	France
29777	36	32	36	40	Please consider adding some information on costs of synthetic hydrocarbons. There could be a reference here to chapter 6, for example from page 6-39 lines 20-22: "The major pathways for methanol, methane, liquid fuel production and cement curing have costs greater than USD 500/t-CO2 (Hepburn et al. 2019)". The IEA Energy Technology Perspectives 2020 also discuss this in the chapter Hydrogen and hydrogen-based fuels, from page 139. From that section the following could be used here (on page 147): " If, for example, synthetic kerosene can be produced at a cost of USD 200/barrel, a CO2 price of USD 375/tonne would be needed for synthetic kerosene to become competitive with fossil kerosene at an oil price of USD 50/barrel. The very high CO2 prices (or equivalent policy measures) that would be needed for synthetic hydrocarbon fuels to compete with fossil fuels means that their use is limited to parts of the energy system where alternative low-carbon options are not viable, such as aviation."	Thak you, this was useful	Government of United States of America	Norwegian Environment Agency	Norway
77801	36	32	36	40	California's Low Carbon Fuel Standard (LCFS) program/market explicitly allows CCS as well as CCU to earn credits if used in lowering the carbon intensity of fuel production or capturing CO2 emissions from ethanol production facilities.	Noted.	Hiroyuki Tezuka	Climate Wedge LLC	United States of America
70457	36	41	37	6	The CCUS paragraph has a strong focus on the use of (mainly fossil) CO2 as a source for fuels. While convenient, there is no fundamental requirement to have carbon based fuels in a net-zero economy. As is correctly recognised, the (extent of the) future demand for hydrocarbon fuels is all but certain. Organic chemicals on the other hand contain carbon by definition and will continue to be used. Relating to chemical industry specifically, the CCUS paragraph could benefit from a stronger focus of CCUS and the use of biogenic carbon in chemicals production. Some topics to be briefly discussed include: the use of drop-in biochemicals (ie bioethylene) vs novel native bioplastics (ie PEF), the development of more efficient routes for the production of biopolymers (ie from sugars directly to specialty chemicals) and recycling of biopolymers.	Chemical feedstocks are listed right after fuels, but we have gone back and woven chemical feedstock needs more clearly int the text.	Government of United States of America	European Union (EU) - DG Research & Innovation	Belgium

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
80681	36	41	36	44	BECCS is not a negative emission strategy in the crucial near term because it results in a carbon deficit for many years, generally several decades to a century. Danielle Venton, Core Concept: Can bioenergy with carbon capture and storage make an impact?, PNAS (2016); Leturcq, P. (2020) GHG Displacement Factors of Harvested Wood Products: the Myth of Substitution, Nature Scientific Reports 10:1–9; Mary S. Booth, Not carbon neutral: Assessing the net emissions impact of residues burned for bioenergy, Environ. Res. Lett. 13 (21 February 2018); Sterman J. D., et al. (2018) Does replacing coal with wood lower CO2 emissions? Dynamic lifecycle analysis of wood bioenergy, Envtl. Research Letters 13(015007):1–10, 1 ("We simulate substitution of wood for coal in power generation, estimating the parameters governing NPP and other fluxes using data for forests in the eastern US and using published estimates for supply chain emissions. Because combustion and processing efficiencies for wood are less than coal, the immediate impact of substituting wood for coal is an increase in atmospheric CO2 relative to coal. The payback time for this carbon debt ranges from 44–104 years after clear-cut, depending on forest type—assuming the land remains forest. Surprisingly, replanting hardwood forests with fast-growing pine plantations raises the CO2 impact of wood because the equilibrium carbon density of plantations is lower than natural forests. Further, projected growth in wood harvest for bioenergy would increase atmospheric CO2 for at least a century because new carbon debt continuously exceeds NPP. Assuming biofuels are carbon neutral may worsen irreversible impacts of climate change before benefits accrue. Instead, explicit dynamic models should be used to assess the climate impacts of biofuels."). Furthermore, even if BECCS were net zero or negative in the relevant next couple of decades, which it is not, large-scale biodiversity development requires vast land-use changes, which may have significant implications for food security and biodiversity. National Academies of Sciences, Engineering, and Medicine, Negative Emissions Technologies and Reliable Sequestration: A Research Agenda,10 (2019) ("Because food demand is expected to double by mid-century, repurposing a significant amount of current agricultural land to produce feedstocks for BECCS or for afforestation/reforestation might have a significant effect on food availability and food prices, with far-reaching effects on national security and biodiversity."). The IPCC Special Report on Climate Change and Land warns that high implementation of BECCS (11.3 GtCO2 yr-1 in 2050) could increase the population at risk of hunger by up to 150 million people and could have significant impacts on desertification and land degradation. IPCC, Summary for Policymakers, In: Climate Change and Land: an IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems, 27 (2019) ("Impacts on adaptation, desertification, land degradation and food security are maximum potential impacts, assuming carbon dioxide removal by BECCS at a scale of 11.3 GtCO2 yr-1 in 2050, and noting that bioenergy without CCS can also achieve emissions reductions of up to several GtCO2 yr-1 when it is a low carbon energy source {2.6.1; 6.3.1}. Studies linking bioenergy to food security estimate an increase in the population at risk of hunger to up to 150 million people at this level of implementation {6.3.5}. The red hatched cells for desertification and land degradation indicate that while up to 15 million km2 of additional land is required in 2100 in 2°C scenarios which will increase pressure for desertification and land degradation, the actual area affected by this additional pressure is not easily quantified {6.3.3; 6.3.4}."). Using BECCS to draw down between 2 and 10 Gt CO2 annually would require the dedication of land equivalent to the size of India, and possibly even double this amount, to support biomass production, introducing daunting logistical issues. Anderson K. & Peters G., The Trouble with Negative Emissions, Science 354:182–183 (2016) ("Moreover, the scale of biomass assumed in IAMs—typically, one to two times the area of India—raises profound questions about carbon neutrality, land availability, competition with food production, and competing demands for bioenergy from the transport, heating, and industrial sectors. The logistics of collating and transporting vast quantities of bioenergy—equivalent to up to half of the total global primary energy consumption—is seldom addressed. Some studies suggest that BECCS pathways are feasible, at least locally, but globally there are substantial limitations. BECCS thus remains a highly speculative technology."). BECCS also faces infrastructure-based limits from the lack of suitable long-distance biomass and CO2 transport. Baik E. et al., Geospatial Analysis of Near-term Potential for Carbon-negative Bioenergy in the United States, Proc. Nat'l. Acad. Sci. 115(13):3290–3295 (2018) ("Previous BECCS deployment assessments have largely overlooked the potential lack of spatial colocation of suitable storage basins and biomass availability, in the absence of long-distance biomass and CO2 transport. These conditions could constrain the near-term technical deployment potential of BECCS due to social and economic barriers that exist for biomass and CO2 transport…If the total biomass resource available in the United States was mobilized for BECCS, an estimated 370 Mt CO2·y−1 of negative emissions could be supplied in 2020. However, the absence of long-distance biomass and CO2 transport, as well as limitations imposed by unsuitable regional storage and injection capacities, collectively decrease the technical potential of negative emissions to 100 Mt CO2 ·y−1."). Moreover, large-scale BECCS could put significant strains on global freshwater use, biosphere integrity, and biogeochemical flows. Heck V. et al., Biomass-based Negative Emissions Difficult to Reconcile with Planetary Boundaries, Nature Climate Change 8:151–155 (2018) ("[W]hile large-scale BECCS is intended to lower the pressure on the [planetary boundaries (PB)] for climate change, it would most likely steer the Earth system closer to the PB for freshwater use and lead to further transgression of the PBs for land-system change, biosphere integrity and biogeochemical flows.").	The details, pros, and cons of BECCS are much more fully considered in Ch.3 and Ch6. We use Helpburn et al 2019 several times, a core resources on net carbon flows.	Jim O'Brien	Institute for Governance & Sustainable Development	United States of America
80681	36	41	36	44	(continuing) Because of its many adverse consequences, bioenergy raises environmental justice issues. Wood pellet production facilities are often located in communities of color and environmental justice communities. Purifoy D., How Europe's Wood Pellet Appetite Worsens Environmental Racism in the South (5 October 2020) ("From Northampton County to Alabama's Black Belt, residents and activists say companies such as Enviva exploit mostly communities of color with promises to build up busted local economies with a "green energy" industry. Instead, communities hosting wood pellet facilities are not only further burdened by pollution and other local dangers, they are also entangled in yet another climate damaging trend — the destruction of biodiverse hardwood forests and the rise of monoculture tree plantations to produce energy that appears to pose climate threats similar to coal."). The production process releases harmful pollutants into the air and increases noise pollution, while the harvesting decreases biodiversity in the surrounding areas. Danielle Purifoy, How Europe's Wood Pellet Appetite Worsens Environmental Racism in the South (5 October 2020) ("Northampton County residents such as Joyner are more immediately concerned about the acute impacts of wood pellet manufacturing, from local clear cutting of privately owned forests to the 24/7 production process. [...] In addition to the noise from grinding trees and truck traffic, Alston and others complain about a constant cloud of dust flowing from the plant onto their homes, cars, gardens and into their lungs. "); Environmental Integrity Project (26 April 2018), Dirty Deception: How the Wood Biomass Industry Skirts the Clean Air Act, 4-5 ("[Environmental Integrity Project's] survey reveals that these facilities emit dangerous amounts of air pollution, and further finds that state agencies consistently fall well short of their duty to ensure that these facilities control their pollution to the levels required by law, frequently due to misleading information supplied by the industry. As a result, many large pellet mills have been allowed to emit air pollution, especially volatile organic compounds (VOCs) and hazardous air pollutants at levels well above legal limits for years at a time."). These harms occur while the industry is falling short of its proposed climate and job goals. Note the environmental movement backlash against BECCS. See Anderson K. & Peters G. (2016) The trouble with negative emissions, SCIENCE 354:182–183.				
80825	36	41	36	44	Even if BECCS were net zero or negative in the relevant next couple of decades, which it is not, CCS has not been perfected at scale nor has it received social acceptability. Governance gaps also exist. See Climate Geoengineering Governance Initiative (C2G2), Governing large-scale carbon dioxide removal: are we ready? (2018); Gregory Nemet et al., Negative emissions—Part 3: Innovation and upscaling, Environ. Res. Lett. (May 2018); European Academies Science Advisory Council, Negative emission technologies: What role in meeting Paris Agreement targets? (Feb 2018) ("CCS plans in Europe have been shelved so that whatever experience is being gained globally is outside Europe. The loss in momentum in implementing CCS technologies not only has serious implications for mitigation pathways, but also one of the most commonly cited NETs [negative emissions technologies] (BECCS) assumes the availability of cost effective 'off-the shelf' CCS, while another (direct air capture) relies on the widespread availability of CO2 storage. At present, economic incentives for deploying CCS are inadequate (whether through the very low carbon price or targeted government support), while those for NET development are lacking."); Andersen & Peters, The Trouble with Negative Emissions, Science (Oct 2016). One study estimates that current rate of increase in CCS is 100 times lower than needed to meet the 2C target. See Haszeldine et al. (April 2018), Negative emissions technologies and carbon capture and storage to achieve the Paris Agreement commitments, Philosophical Transactions of the Royal Society.	Thanks, this is not the place to elaborate on BECCS. More detail is in Ch7 and Ch12	Tennant Reed	Institute for Governance & Sustainable Development	United States of America
43911	37	1	37	6	"Methanol Economy" is a concept that has been adovocated for decades (e.g., by Nobel Prize winner Prof George Olah), this concept encourages the use of methanol as a feedstock for fuels and chemicals. Currently China is the only country has been practicing this concep. I suggest mentioning about this imporant concept about using methanol here and I recommended the following literature: (1) Beyond Oil and Gas: The Methanol Economy, George A. Olah Dr. Alain Goeppert Prof. Dr. G. K. Surya Prakash. DOI:10.1002/9783527627806; (2) Environmental implications of the methanol economy in China: well-to-wheel comparison of energy and environmental emissions for different methanol fuel production pathways. Journal of Cleaner Production, Volume 172, 2018, Pages 1381-1390, https://doi.org/10.1016/j.jclepro.2017.10.232.	Methanol is included in all our discussions.	Government of United States of America	Yale University	United States of America
76493	37	21			This is an important point. I would appreciate if there was more analysis in this entire section. The amounts of carbon used in potential long-term and permanent use applications would be an important piece of information. A lot of the literature on CCU is very naive and ignores the issue of the size of material flows. The material flows of fuels are much larger than the flows of carbonaceous materials.	I agree with you, but we've already allocated as much space as we can. Also, MacDowell et al does the most thorough job, and is a high level paper that speaks for itself.	Richard Bohan	Norwegian University of Science and Technology	Norway
3703	38	3	38	7	To inform this we draw from a literature that has emerged largely since AR5 was completed … rest of the economy. Sentence is weird. Rephrase.	Done	Jim O'Brien	Mines Saint-Etienne	France
29779	38	11	38	11	Please consider to add bio-CCS in the industrial sector here. For example, "[..], fossil and biomass use with CCS, [..]". Co-firing waste containing biomass with fossil energy is for example already standard procedure in cement kilns and waste-to-energy plants, which perhaps is the installations in this sector most likely to require CCS for deep decarbonisation. Some industries, like pulp and paper, also have large point sources of biogenic CO2 from burning of waste, which could use CCS to achieve negative emissions.	Added.	SAI MING LEE	Norwegian Environment Agency	Norway
14995	38	13	38	14	The following draft text is quite attractive but a reference literature showing Figure 11.9 is missing. So, please indicate it at the end of the sentence. "there is no 'silver bullet' and so all behavioural and technological options have to be mobilised (Figure 11.9)."	Done	Hiroyuki Tezuka	Japan Cement Association	Japan
28471	38	14	38	20	The key conclusion should be that through a variety of option net-zero emissions at largest industrial sources can be achieved within the next decades not "later this century".	Agree, edited.	Lucas Desport	Bellona Europa	Belgium
29781	38	20	38	24	Please consider rephrasing this sentence. This chapter describes in detail the considerable technological and institutional challenges involved in decarbonising the production of basic materials, and so does the sited sources. `Hard to abate` is a shorthand used in policy discussions and is not defined here, so any judgement on whether this sector can be described as such seems difficult without some further elaboration. Alternatively a definition could be proposed in the appropriate part of this report, as `hard to abate` and `hard to decarbonise` are also used elsewhere.	Paragraph simplified and shortened.	Christian Breyer	Norwegian Environment Agency	Norway
2383	38	20	38	23	Re "hard to transition" might be more appropriate, with more emphasis required on the policy mechanisms necessary to engage a challenging transition in highly competitive, currently GHG intense, price sensitive sectors." In my opinion this distinction is not helpful. The key is the velocity of the transition that is needed to reach net zero GHG in industry and overall. Negative emissions scale up to Gigatons CO2 in 20-30 years is simply not realistic; thus industry emissions need urgent policy/measures/investments to decarbonize in a few decades.	Paragraph simplified and shortened.	Célia Sapart	Lawrence Berkeley Lab	United States of America
57421	38	25	38	25	Refer to Figure 11.9 here.	Done	Cécile Seguineaud	U.S. Department of State	United States of America
29783	38	27	38	30	Consider rephrasing or deleting this sentence, as it implies that CCS is a less desirable mitigation option than other strategies. This can be read as policy prescriptive/biased.	Removed.	Government of United States of America	Norwegian Environment Agency	Norway
2381	38	30	38	31	"But this reflects the growing demand for new energy and material intensive service and so loop is closed." : I'm not sure what the import of this sentence is? Can it be rewritten and clarified?	Editing error, was supposed to be removed	Tennant Reed	Lawrence Berkeley Lab	United States of America
29785	38	30	38	31	Consider rephrasing the sentence beginning with " but this reflects..", as it is difficult to ascertain its meaning as it stands.	Editing error, was supposed to be removed	NAOKI AOKI	Norwegian Environment Agency	Norway
76495	38	30	38	31	meaning of sentence is unclear	Editing error, was supposed to be removed	Mariesse van Sluisveld	Norwegian University of Science and Tech	Norway
47275	38	32	38	49	It could be nice to make a link here to the insights from Chapter 5 (covering circular economy) touching upon the industrial ecology literature looking into material stocks, secondary markets, cascading effects, service-level efficiency, urban mining etc.	Transfer to Yang	Government of United States of America	PBL Netherlands Environmental Assessme	Netherlands
57423	38	32	38	32	Start this section with a definition of circular economy.	The first sentence does this from our perspective	Government of Kenya	U.S. Department of State	United States of America
57425	38	38		49	Prefabricated methods provide a number of potential reductions, through modularized production, and recyclable parts and material. It can also be built fast, getting to scale quickly.	Noted.	Government of Germany	U.S. Department of State	United States of America
57427	38	40	38	40	Instead of "well-made" say "high-quality"	Done	Mariel Vilella	U.S. Department of State	United States of America
57429	38	42	38	42	"off-sight" should be "off-site"	Done	JAE YOON LEE	U.S. Department of State	United States of America
2259	38	42	38	44	(e.g. wood)→ such as wood	Done	Eric Masanet	Hongik University	Republic of Korea
16559	38	42	38	44	(e.g. wood)→ such as wood	Done	Cédric PHILIBERT	Korea Meteorological Administration (KM	Republic of Korea
2385	39	1	39	5	Energy efficiency and equipment or plant lifetime is a tricky issue for fossil fuel plants. Given that equipment can last for 20-30 years or more (factories even longer), how much investment should be made on improved energy efficiency in fossil-fuel based plants in say 2025 or 2027? For zero carbon and assuming negative emissions cannot scale up by 2050, new fossil based equipment and plants should not be built after 2030 at the latest.	Edited, put EE in context of net-zero.	Cédric PHILIBERT	Lawrence Berkeley Lab	United States of America
57431	39	1	39	5	What does energy efficiency in use refer to? Use of what? What does upstream supply material mean? There are no references in this paragraph. Re-write as: "There are myriad ways to reduce specific energy use in industry, including adoption of more efficient technologies or processes, specific equipment retrofits, increased thermal insulation, use of waste heat for pre-heating, and improved/streamlined operational and control practices."	Edited, put EE in context of net-zero.	Cédric PHILIBERT	U.S. Department of State	United States of America
57433	39	1	39	5	This section talks about the interaction and the importance of each strategy in deep decarbonization. Energy efficiency has several other values and iterations which could be highlighted. Additional language could include: "" "" While energy efficiency and circular economy are often treated as two separate activities, they inherently support the same principle of efficiently using a resource to its maximum potential.	Edited. Thank you.	Cédric PHILIBERT	U.S. Department of State	United States of America
57435	39	1	39	5	Lots of other energy efficiency measures are also worth mentioning here, such as energy management systems, smart manufacturing systems, sensors and controls, tools/guidebooks, and energy assessment on cross-cutting energy systems (process heating, steam, motors, etc.).	Edited	Cédric PHILIBERT	U.S. Department of State	United States of America

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
57437	39	6	39	11	The examples given would be more effective in the relevant individual sections than the summary.	Edited	Reid Miner	U.S. Department of State	United States of America
57439	39	11	39	12	What about electricity generation and distribution losses?	Edited	Government of United States of America	U.S. Department of State	United States of America
70459	39	11	39	12	The future energy system will be largely based on electricity from renewable sources rather than the thermal conversion of mined fuels into electricity. As such, the efficiency of electricity production from primary energy is only of short term concern. Consider removing this sentence or instead expanding on the issue by adding the context in this comment.	Edited	Damien Lamy	European Union (EU) - DG Research & Innovation	Belgium
76497	39	12	39	15	Thermodynamics also applies to electrochemical reactions. I think a statement like this is misplaced here, as it refers to technologies that exist at the laboratory scale and there do not cover the entire production chain. A more rigorous review of these claims is required if the IPCC would like to make statements about it. I would like to point to this paper https://doi.org/10.1016/j.jclepro.2013.11.046 which found that electrochemical reduction of CO2 to formic acid caused much larger GHG emissions than the conventional route from natural gas and that the purification step was the real challenge.	We have kept the section, but added a caveat as per the comment.	Cédric PHILIBERT	Norwegian University of Science and Technology	Norway
76499	39	16	39	22	For contect, I suggest adding information on the size of the use of organic materials compared to the size of the stream of fossil fuels.	This comes in 11.4	Government of United States of America	Norwegian University of Science and Tech	Norway
46123	39	18	39	18	Please add "in the future possibly" before chemical recycling. Chemical recycling is not yet a standard state of the art technology and it's environmental benefit is not yet proven, therefore it should not be on the same level as mechanical recycling. (Reference: https://www.umweltbundesamt.de/sites/default/files/medien/5750/publikationen/hgp_chemischesrecycling_englisch_bf.pdf)	Noted	Reid Miner	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety International Climate Policy	Germany
2387	39	23	39	30	The discussion of interactions of bioenergy, H2, electrification, synfuels or e-fuels is important to include. But does this chapter have discussion of timeframes for massive energy transitions? These typically take 40-100 years -- we do not have time for that for scaling up e-fuels with DAC; DAC; or BECCs. To me this suggests some drastic course of action is needed -- see my comments below.	Noted	Government of United States of America	Lawrence Berkeley Lab	United States of America
57441	39	32	39	33	Suggested re-write: "Energy efficiency is a relatively mature strategy, but technology development and increased adoption and improved utilization of both new and existing energy efficiency measures leads to continued potential for savings." Energy efficiency isn't just about new technologies. It's also about managing the production process to constantly minimize energy losses. It's about constantly being vigilant about operational practices, maintenance, and continuous improvements. It's about adopting existing energy efficiency technologies that aren't currently in a particular plant. It's about driving down the cost of existing energy efficiency technologies so that there is more widespread adoption.	Noted	Government of United States of America	U.S. Department of State	United States of America
82773	40	1	40	1	consider using bullets in the cells to separate recommendations; since the built environment is so important for ME and CE, consider creating a separate row for architects, civil engineers, builders, and property owners since these stakehoders may not consider themselves as part of "industrial sectors or associations"	Table edited using multiple reviwer comments	Jeffrey Merrifield	Northwestern University	United States of America
17869	40	1	40	2	Instead of "Resolve long-term accountability" in row 5 column 8 – "liabilities" is a better term, since it conveys a particular meaning.	Table edited using multiple reviwer comments	Mariel Vilella	Global CCS Institute	Belgium
57443	40	1	40	2	In Table 11.2, changing the order of actors (Corporations, Industrial Sectors, Civil Society, Regional and National Governments, International) would be more effective because it would show the possible actions from smallest scale to largest.	Table edited using multiple reviwer comments	Government of United States of America	U.S. Department of State	United States of America
70461	40	1	40	24	The table as it stands now is too much enginering oriented. It would be good if the final table would indeed include various instruments that work with carbon prices and information that would guide the transition in the right direction. This could be e.g. carbon taxes installed by national or intl. govt, bodies, but also use of carbon pricing in green procurement, both from companies and govrernments, carbon footprinting as information instrument to guide buyers in purchasing low carbon products over the entire chain, etc..	Table edited using multiple reviwer comments	Eric Masanet	European Union (EU) - DG Research &amp	Belgium
57453	40	2			What about standardization tools or guidebooks that are easy to use to address the information gap?	Table edited using multiple reviwer comments	Government of United States of America	U.S. Department of State	United States of America
57455	40	2			Codes or standards that incorporate carbon content, incentives, or other policies that help create the market pulls will be very important.	Table edited using multiple reviwer comments	Government of United States of America	U.S. Department of State	United States of America
57445	40	2	40	2	In Table 11.2, should the second column be "Demand reduction measures" or "Demand control measures"?	Table edited using multiple reviwer comments	PINAKI SARKAR	U.S. Department of State	United States of America
57447	40	2	40	2	In Table 11.2, for the box under energy efficiency/regional and national government, and cities, insert: "Continue and develop energy efficiency policies such as incentives, standards, labels, benchmarks, and disclosure requirements."	Table edited using multiple reviwer comments	Government of United States of America	U.S. Department of State	United States of America
57449	40	2	40	2	In Table 11.2, include procurement policies around buying energy efficient building materials and products at the intersection of Regional and national government, and cities and Energy Efficiency. Just within the last several years there has been a swell of Buy Clean Acts at the state level in the U.S. See map at https://carbonleadershipforum.org/what-is-a-buy-clean-policy/ Similarly suggest including seek third-party certification for energy efficiency at the intersection of Corporation and companies and Energy Efficiency.	Table edited using multiple reviwer comments	Eric Masanet	U.S. Department of State	United States of America
57451	40	2	40	2	Table 11.2 called out Industrial Sectors and Associations / Electrification, hydrogen and fuel switching. One of the key elements is supporting innovation, sharing best practices, and "demonstrating social proof of concept." Leadership through social proof demonstration is a key element of ensuring that strategies take root and grow.	Table edited using multiple reviwer comments	Government of United States of America	U.S. Department of State	United States of America
3705	40				last row : RD&D -> R&D ?	Table edited using multiple reviwer comments	Government of United States of America	Mines Saint-Etienne	France
72843	40		40		Table 11-2 is very interesting and useful, but maybe a few additions are possible (or in the text to avoid too much info in the table). First, civil society could include choice of consumers in a way or another e.g. choose a car with the right label of low carbon. Second, industrial sectors and associations may include bodies in capacity to sign mandatory agreements or tax modifications with governments (e.g. in Switzerland or Scandinavia), in many other countries the branches have no say and are not representative enough (France). Third, maybe a whole line (or a comment in the text) could mention the specific case of multinational companies, which can spread rules or practices imposed in one country and not another.	Table edited using multiple reviwer comments	Richard Bohan	EE-Consultant	France
84913	40		41		This table is missing two big categories: the research community as a set of actors, and educational or workforce interventions as an otion for actions. Also, the mention of "lobby efforts" for civil society is probably more appropriately referred to as "advocacy" and it could apply in all categories.	Table edited using multiple reviwer comments	Government of United States of America	ClimateWorks Foundation	United States of America
76501	40		41		It would be good if the table reflected a synthesis of specific research. Currently, there are no references provided. The IRP RECC report already cited contains a policy review chapter which takes on the issue of material efficiency in buildings and for cars, and has quite a lot of relevant findings. For example, it finds that building and construction standards and certification systems (such as LEED and BREEAM) can provide incentives for material efficiency and circularity in buildings. Taxation was an important issue, in particular virgin material extraction SUBSIDIES which need to be removed. Basing relevant regulations and financial incentives on life-cycle emissions was important. Planning and zoning rules influenced whether more material efficient multifamily homes could be constructed, but also which form the homes take. Companies have a leading role in identifying and commercializing material efficient and circular solutions,depending on the sector. They need both incentives and an innovative mindset.	Table edited using multiple reviwer comments	Government of Saudi Arabia	Norwegian University of Science and Technology	Norway
57459	41	1			In the Table 11.2 cell at Industrial Sectors and Associations / Electrification hydrogen and fuel switching, consider adding "(increasing grid balancing areas to foster greater access and reliability to variable resources)"	Table edited using multiple reviwer comments	Government of United States of America	U.S. Department of State	United States of America
57457	41	1	41	1	In Table 11.2, last column (Civil society) for the energy efficiency box, include actions such as information and advocacy related to energy efficiency policies, lobbying, and monitoring progress.	Table edited using multiple reviwer comments	Christian Breyer	U.S. Department of State	United States of America
77799	41	37	41	39	It can be noted that "clinker displacement" GHG abatement projects, in particular substitution of clinker with coal fly ash or other aggregates, was a widely adopted GHG offset project type under the Clean Development Mechanism of the Kyoto Protocol (see e.g. https://cdm.unfccc.int/methodologies/DB/8U4CEW1DGPRKCIXFKTQ4FURFTPIAZC, which was the UN's officially approved clinker replacement methodology under the CDM).	Table edited using multiple reviwer comments	Mariesse van Sluisveld	Climate Wedge LLC	United States of America
11483	42	6	42	7	Table 11.3 is empty. Please check.	Fig 11.10 and the preceding table are to be harmonized and moved ot the end of 11.4.	Richard Bohan	Hong Kong Observatory	China
2261	42	6	42	7	Table 11.3 : incomplete	Fig 11.10 and the preceding table are to be harmonized and moved ot the end of 11.4.	Eric Masanet	Hongik University	Republic of Korea
16561	42	6	42	7	Table 11.3 : incomplete	Fig 11.10 and the preceding table are to be harmonized and moved ot the end of 11.4.	Hiroyuki Tezuka	Korea Meteorological Administration (KM	Republic of Korea
39063	42	6	42	7	Please add content in table 11.3 Assessment of apportionment of mitigation by strategy	Fig 11.10 and the preceding table are to be harmonized and moved ot the end of 11.4.	Government of United States of America	Independent Researcher	India
3707	42				even if mentioned that the team is discussing the place where the table belong, it is empty, so don't forget to fill it	Fig 11.10 and the preceding table are to be harmonized and moved ot the end of 11.4.	Durwood Zaelke	Mines Saint-Etienne	France
84915	42		42		What would this table show?	Fig 11.10 and the preceding table are to be harmonized and moved ot the end of 11.4.	Gabrielle Dreyfus	ClimateWorks Foundation	United States of America
39065	43	1	43	1	The point that the figure is trying to communicate is not very clear. Could consider simplifying the figure	Fig 11.10 and the preceding table are to be harmonized and moved ot the end of 11.4.	Cédric PHILIBERT	Independent Researcher	India
45589	43	1	43	1	This is a very nice graphic!	Fig 11.10 and the preceding table are to be harmonized and moved ot the end of 11.4.	Cédric PHILIBERT	Delft University of Technology	Netherlands
82775	43	1	43	1	consider using more distinctly different colors for the different strateges; the shades of blue are difficult to distinguish. Also consider better explaining what the orange shaded areas are depicting over time ... is the height of the area in a given year meant to capture the range of estimates?	Fig 11.10 and the preceding table are to be harmonized and moved ot the end of 11.4.	Government of United States of America	Northwestern University	United States of America
57461	43	1	43	14	In Figure 11.10, it's unclear what the "costs rise" value represents. For example, 'cement - 35%-115%' means what? The cost per ton of cement? When? Under what assumptions? Why such a large range? Similarly confused about all of the other "costs rise" values in this figure. The key shows CIE1, but the title has CIEL. Fix the key. In the figure caption, some of abbreviations used are defined, but not all. The circles all seem to reflect the status in 2050 and 2070, but the figure title says "... are shown for 2050 (2040) and 2070." Should (2040) be removed? This figure needs to be more fully explained in the text. It is merely called out on page 44, without explanation.	Fig 11.10 and the preceding table are to be harmonized and moved ot the end of 11.4.	Hiroyuki Tezuka	U.S. Department of State	United States of America
57463	43	1	43	14	This comment addresses the Figure 11.10 waterfall graphs: 1. Change titles. Authors should say something about components of carbon reduction in the title under two scenarios and move the ""costs rise"" to a place under each graph or to the notes. 2. Separate the waterfall from the carbon reduction. First, make the carbon reduction part of the graph narrower, so there's room to put the waterfall in a section of its own. Clearly title the 2050 and 2070 waterfalls. 3. When separating the waterfall charts, change the x-axis on the waterfall chart to represent carbon costs. Also, the bars will need to get a lot fatter to denote the cost ranges at which each carbon reduction method is viable. While the resulting charts will no longer be true waterfalls because of overlap, that's OK. 4. For cement, it looks as if mitigation exceeds the amount of emissions. Does that mean emissions can be sold in a cap and trade scheme or be offset? Perhaps authors should extend the cement graph to negative carbon values?	Fig 11.10 and the preceding table are to be harmonized and moved ot the end of 11.4.	Government of United States of America	U.S. Department of State	United States of America
57465	43	1	43	14	This comment addresses the Figure 11.10 donuts graphs. This element of the graphic is easier to understand, and should perhaps be considered for inclusion on its own. There's a typo on primary chemicals (1.24 in 2050).	Fig 11.10 and the preceding table are to be harmonized and moved ot the end of 11.4.	Tennant Reed	U.S. Department of State	United States of America

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
2263	43	1	43	2	Fifure 11.10. You need to edit the subject line. CIE1, EE, ME, FeedC1, FSW+EI : Needs additional explanation	Fig 11.10 and the preceding table are to be harmonized and moved ot the end of 11.4.	Philippe Tulkens	Hongik University	Republic of Korea
16563	43	1	43	2	Fifure 11.10. You need to edit the subject line. CIE1, EE, ME, FeedC1, FSW+EI : Needs additional explanation	Fig 11.10 and the preceding table are to be harmonized and moved ot the end of 11.4.	Government of France	Korea Meteorological Administration (KM	Republic of Korea
30575	43	1	44	6	Figure 11.10 suggests that net zero emissions in the industrial sector are possible at relatively low carbon prices. If Figure 11.10 is shown, it would be better to describe that the industrial sector is on par with or easier to reach net zero emissions than the electricity sector.	Fig 11.10 and the preceding table are to be harmonized and moved ot the end of 11.4.	Suyi Kim	Climate Change Division - Ministry of Fore	Japan
70463	43	1	44	6	The figure as it currently stands is very hard to read and understand due to the information density and is not properly linked to the preceding text. Consider using multiple colours for the different strategies rather than 7 shades of blue. The figure also raises some questions without further context: why can't all emissions be abated before 2050? Why is the share of mature technologies higher in 2050 than in 2070 for all technologies? Consider breaking up the figure in 4 subfigures and discussing each in more detail in the appropriate paragraph of Ch.11.4 or giving a better introduction to the figure.	Fig 11.10 and the preceding table are to be harmonized and moved ot the end of 11.4.	Government of Republic of Korea	European Union (EU) - DG Research &amp	Belgium
3647	43	2	44	4	In Page 11-43 Figure 11-10 indicates that Green steel cost rise is to be "10-50%" and its impact on cars and homes will be less than 1%. Cost penalty number is slightly different from the executive summary.	Fig 11.10 and the preceding table are to be harmonized and moved ot the end of 11.4.	Hiroyuki Tezuka	JFE Steel Corp.	Japan
57469	43	2			Would it be possible to use these data to produce a summary table with estimated "residual emissions" per sector in 2050? Independent estimates of residual emissions would be helpful for voluntary carbon markets and net-zero frameworks.	Fig 11.10 and the preceding table are to be harmonized and moved ot the end of 11.4.	Government of Norway	U.S. Department of State	United States of America
57467	43	2		6	Should this be moved to page 55, when cost of technology and potentials are discussed?	Fig 11.10 and the preceding table are to be harmonized and moved ot the end of 11.4.	Eric Masanet	U.S. Department of State	United States of America
43959	43				Figure 11.10: IPCC does not take into account the impacts of leakage in the analysis. The impact of a large increase in cost for certain materials, including cement and concrete, will have a severe impact on domestic cement plants, particularly where only a subset of nations implement carbon reductions. PCA has estimated that even a 10% relative increse in the price of U.S. cement could increase imports by 30 percent, increasing higher-carbon imports and increased shipping emissions.	Fig 11.10 and the preceding table are to be harmonized and moved ot the end of 11.4.	Damien Lamy	Portland Cement Association	United States of America
76503	43				I do not understand what this figure is meant to represent or how it has been constructed and where the information comes from.	Fig 11.10 and the preceding table are to be harmonized and moved ot the end of 11.4.	Ken Oshiro	Norwegian University of Science and Tech	Norway
84917	43		43		This figure is potentially fascinating, but in its current form it is VERY confusing. I stared at it for several minutes trying to work out what was going on, and I still think I only got about half of it. In order for it to be useful, it is critical that more of the information needed to interpret it be actually spelled out in the graph itself, as opposed to in the caption--going back and forth trying to match acronyms, colors, and substance across not just different categories but different types of categories just isn't working.	Fig 11.10 and the preceding table are to be harmonized and moved ot the end of 11.4.	JAE YOON LEE	ClimateWorks Foundation	United States of America
84919	43		43		I was surprised to see an average CO2 intensity of <0.6tCO2 per t cement cited to Crippa, et al. I frequently use that dataset, and it has a total emissions from the cement sector of 3.9 GtCO2 in 2018, which is nearly 1t CO2 per t cement. I consider this number implausibly high, but there does seem to be a mismatch between your number and the souce you cite.	Fig 11.10 and the preceding table are to be harmonized and moved ot the end of 11.4.	Philippe Tulkens	ClimateWorks Foundation	United States of America
57471	44	11	44	11	Section 11.4 should also discuss the barriers of mitigation pathways.	Noted	Hiroyuki Tezuka	U.S. Department of State	United States of America
57473	44	11	44	11	This section discussed multiple sectors. It would be very helpful to include a short discussion/figure to re-emphasize the energy and emissions breakdown by key industries.	Interesting idea, but we are short of space.	Eric Masanet	U.S. Department of State	United States of America
43023	44	16	44	17	Market penetration happens in all years after a technology or process is introduced. So the phrase 'potential year of market penetration' is suggested to be rephrased to imply the year in which the technology is introduced to the market	Edited	Government of United States of America	Independent Researcher	India
72845	44	18	44	20	The sentence could be shortened and focused	Edited	Eric Masanet	EE-Consultant	France
72847	44	26	44	28	The sentence could be shortened and focused	Edited	Richard Bohan	EE-Consultant	France
72849	44	34	44	34	Mind set? Maybe "behavioural attitudes" ? Or "acceptation of change" ?	Edited	Eric Masanet	EE-Consultant	France
72851	44	42	44	42	Remove the part under brakets. Neither vehicule batteries nor photovoltaïc module use rare earth. Maybe "rare earth for some electric vehicules" is better because part of the market uses permanent magnets with rare earth (but not the Reneout Zoé nor Tesla)	Edited	Miguel Angel Sanjuán	EE-Consultant	France
84921	44		44		I was confused by the discussion in the caption of direct and indirect steel emissions. Surely it would be better to just use primary steel production numbers in this figure so the BF/EAF confusion can be side-stepped?	The comment is missmapped, I don't know where it relates to.	Changke WANG	ClimateWorks Foundation	United States of America
84931	44		53		All of the sector-specific discussions include a sentence at the end saying "estimates of abatement costs vary" with some citations. Obviously. It would be more helpful to specify ranges or other aspects of what makes them vary.	Rewrite clarifies that costs are table later in 11.4.x	Philippe Waldteufel	ClimateWorks Foundation	United States of America
57475	45	2			There may be some redundant information in this and the section above, whether its on emerging technologies such as CCS and hydrogen, or on material efficiency.	We chose to introduce the strategies singly in 11.3 and then combine htem in 11.4.	PEDRO MORA PERIS	U.S. Department of State	United States of America
82823	45	2	45	2	Section 11.4.1 it would be very helpful for the reader if within the subsections for each industry sector (steel, cement, etc.) the authors could use a common narrative structure organized around the strategies depicted in Figure 11.9 (energy efficiency, ME, fuel switching, circularity). Each of these industry sector sections is presented somewhat differently with uneven coverage of the different strategies; since the authors did a very good job of organizing the first third of the chapter around those meta-strategies, it would be helpful to keep that conceptual theme going in the way the sector opportunities are described.	We will conisder this in the final edit through.	sadegh zeyaeyan	Northwestern University	United States of America
29787	45	3	45	6	Please add some more information on the scope of the following sup-chapters. They seem to focus rather less on reducing emissions from existing facilities than options which would entail building new facilities with new technology. Lock-in and stranded assets seems to be of concern in this sector given the very long technical lifetimes and capital intensiveness of these investments.	In the Industry chapter, due to long lived facility lives and challenges with retrofitting, to fcous on what is needed such that all new facilities are near zero on their next rebuild or major retrofit. We will address this in the final edit.	PEDRO MORA PERIS	Norwegian Environment Agency	Norway
72855	45	3	45	5	It would be helpful here to annouce in this paragraph that tentative timelines and cost estimates are given in a table (11.4) at the end of the part p.54.	Done	Aniceto Zaragoza	EE-Consultant	France
57477	45	8	46	44	CCS for Blast Furnace is not discussed properly. With 70% of world production from BF-BOF, most of which has less than 15-year lifetime, CCS for BF-BOF must be considered a major option. That's what steel companies are looking at.	Noted	Eric Masanet	U.S. Department of State	United States of America
84923	45	8	46	44	The steel section could be strengthened by a couple sentences clearly describing the overall dynamics of steel production: countries have highest demand as they move from low to middle income, after which their demand levels off or declines; demand is increasing over time because of development; scrap availability is also increasing at very roughly the same rate as overall demand, meaning that the demand for primary steel is unlikely to increase or decrease dramatically in the next couple decades, but the geographic distribution of demand might change dramatically. This would also allow you to contextualize the comment about waste copper, and explain that it's a problem because as the copper accumulates and the overall ratio of secondary to primary production increases, it will eventually force us to landfill steel instead of recycling it.	Noted, and edited	Mariesse van Sluisveld	ClimateWorks Foundation	United States of America
84925	45	8	46	44	The steel section had a bunch of uncited important numbers, including 15% (p45, l21) and 30% (p45, l41)	The former was sourced and the latter removed.	Government of United States of America	ClimateWorks Foundation	United States of America
84929	45	8	46	44	This section goes out of its way to discuss the weird little bits of CO2 emissions that remain with recycling, HDRI, MOE, and other near-zero emissions pathways, including the need to add C to the Fe metal to turn it into steel. This doesn't seem like it's terribly relevant or would be of general interest, and the details are distracting and potentially confusing.	This section as edited to reflect a batch of comments, including to add syngs DRI EAF with CCS, remove unsourced values, and refined for recent literature	Eric Masanet	ClimateWorks Foundation	United States of America
57479	45	9	45	15	Recommend switching the order of the first two sentences.	This section as edited to reflect a batch of comments, including to add syngs DRI EAF with CCS, remove unsourced values, and refined for recent literature	Government of United States of America	U.S. Department of State	United States of America
84927	45	9	45	12	Why did you cite steel production numbers from 2017? WSA has published the 2020 numbers.	This section as edited to reflect a batch of comments, including to add syngs DRI EAF with CCS, remove unsourced values, and refined for recent literature	Government of United States of America	ClimateWorks Foundation	United States of America
57481	45	16	45	16	Add after "on steel scrap": "… and sometimes coal- and natural gas-fired direct reduced iron (DRI)."	This section as edited to reflect a batch of comments, including to add syngs DRI EAF with CCS, remove unsourced values, and refined for recent literature	Aniceto Zaragoza	U.S. Department of State	United States of America
57483	45	21	45	22	This sentence "An estimated 15% energy efficiency improvement is possible within the basic oxygen furnace (BOF) process" seems out of place here. Perhaps it should go at the end of the above paragraph. In any case, this paragraph would be much better if it started with the second sentence "Several options …"	This section as edited to reflect a batch of comments, including to add syngs DRI EAF with CCS, remove unsourced values, and refined for recent literature	Government of Iran	U.S. Department of State	United States of America
29789	45	27	46	21	Consider adding DRI-EAF with CCS to this list. Given that syngas DRI-EAF is already mature and generate an off-gas of concentrated CO2, this option offers a relatively inexpensive way of reducing emissions from primary steel production. Reference: IEA Energy Technology Perspectives 2020, chapter "Steel production" from page 198.	This section as edited to reflect a batch of comments, including to add syngs DRI EAF with CCS, remove unsourced values, and refined for recent literature	Jim O'Brien	Norwegian Environment Agency	Norway
57485	45	27	45	28	Put a more quantitative number on the "significant" savings by switching from BF-BOF to EAF. 60%?	This section as edited to reflect a batch of comments, including to add syngs DRI EAF with CCS, remove unsourced values, and refined for recent literature	Richard Bohan	U.S. Department of State	United States of America
57487	45	27	45	36	On page 46, lines 31-33, authors state "Recycling would cut the average CO2 emissions per tonne of steel produced by 60% (Material Economics 2019), but globally secondary steel production is limited to 40% in various scenarios (IEA, 2019b)." Shouldn't this information be included on page 45, lines 27-36, where increasing the share of the secondary route is discussed?	This section as edited to reflect a batch of comments, including to add syngs DRI EAF with CCS, remove unsourced values, and refined for recent literature	Alex Rau	U.S. Department of State	United States of America
57489	45	30	45	30	Provide a reference for "85% of steel is recycled already." Is this globally?	This section as edited to reflect a batch of comments, including to add syngs DRI EAF with CCS, remove unsourced values, and refined for recent literature	Miguel Angel Sanjuán	U.S. Department of State	United States of America
57491	45	30	45	30	"85% of steel is recycled already." Also address % of EAF, or how much recycled steel went into EAF.	This section as edited to reflect a batch of comments, including to add syngs DRI EAF with CCS, remove unsourced values, and refined for recent literature	Aniceto Zaragoza	U.S. Department of State	United States of America
69867	45	37	45	45	It might be of interest to note that DRI has already been operated at commercial scale with pure hydrogen at Circored, in Trinidad from 1999 to 2007. The choice was purely technical, and hydrogen was "grey", coming from steam methane reforming. See Nuber D. et al. 2006, Circored fine ore direct reduction, Millenium Steel	This section as edited to reflect a batch of comments, including to add syngs DRI EAF with CCS, remove unsourced values, and refined for recent literature	PEDRO MORA PERIS	Institut Français des Relations Internationales	France
57493	46	29	46	31	Over what period of time are these savings? Up to 24% of cement and 40% of steel demand could be plausibly reduced through strong material efficiency efforts. Potential material efficiency contribution for the EU is estimated to be much higher 48%.	This section as edited to reflect a batch of comments, including to add syngs DRI EAF with CCS, remove unsourced values, and refined for recent literature	Government of United States of America	U.S. Department of State	United States of America
29791	46	33	46	37	Consider expanding on this issue, for example by including this sentence from IEA: "If technologies that apply CCS to blast furnaces are successfully commercialised, they could enable retrofits and thus play an important role in addressing emissions from plants already built or to be built in the next decade." IEA Energy Technology Perspectives 2020, page 209.	This section as edited to reflect a batch of comments, including to add syngs DRI EAF with CCS, remove unsourced values, and refined for recent literature	Government of United States of America	Norwegian Environment Agency	Norway
72853	46	39	46	41	The sentence is used twice	Thank you.	Philippe Tulkens	EE-Consultant	France
57495	47	1	47	1	It would be helpful if Section 11.4.1.2 could also capture: (1) CO2 mineralization or carbonization of concrete technology in cement and concrete, as an emerging technology to use and capture CO2; and (2) the key barriers to adopt / scale-up each of these technology pathways.	paragraph added on this in 11.3.6, other reviwers said the same	Government of United States of America	U.S. Department of State	United States of America
57497	47	1	48	20	Also mention indirect calcination where heating is electric (not fuel used in calciner). This combined with CCS has major carbon reduction advantage from both energy and process CO2.	Already included in cement section	Government of China	U.S. Department of State	United States of America
78773	47	1	48	20	raw material related emissions of the cment industry could be at least partly mitigated if coupled to CCU processes, as detailed by Farfan et al. (https://www.sciencedirect.com/science/article/pii/S0959652619302185)	This is included in the text.	Government of China	LUT University	Finland
80391	47	1	48	20	The issue of waste derived fuels in cement industry is of paramount importance. The text here addressing this sector should include related texting and a small paragraph that the sector is utilised many forms of waste derived fuels in clinker production. e.g. https://doi.org/10.1108/MEQ-01-2015-0012, https://doi.org/10.1016/j.conbuildmat.2017.07.102, https://doi.org/10.1016/j.rser.2017.10.065	Non bioenergy waste fuels produce CO2 when combusted.	Government of United States of America	University of West Attica, Department of Electrical and Electronics Engineering	Greece
52555	47	6	48	20	There is also the option to upgrade existing dry kilns with pre-heaters/heat recovery and pre-calciners, not necessarily install new kilns for clinker production. This has not been mentioned in the text in the context of energy-related GHG emissions. Source: Worrell, Ernst (2008). "Energy efficiency improvement opportunities for the cement industry." LBNL: pages 8-11. (also applies to Table 11.4)	This has already been mentioned.	Government of United States of America	Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
3523	47	8	47	8	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	This not a necessary reference.	Eric Masanet	IECA	Spain
3529	47	8	47	8	Please, add after Schneider 2019: "Sanjuán et al 2020". Please, add the following updated information: 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 "According to Sanjuán et al 2020, currently, cement production is considered as responsible for approximately 7.4% of the global carbon dioxide emission (2.9 Gtons in 2016)." 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	This not a necessary reference.	Government of United States of America	IECA	Spain
10413	47	8	47	8	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	Reject, we already use key references and the suggested article states 7.4 % without reference.	Leila Rashidian	Oficemen	Spain
10419	47	8	47	8	Please, add after Schneider 2019: "Sanjuán et al 2020". Please, add the following updated information: 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 "According to Sanjuán et al 2020, currently, cement production is considered as responsible for approximately 7.4% of the global carbon dioxide emission (2.9 Gtons in 2016)." 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	Reject, we already use key references and the suggested article states 7.4 % without reference.	Behzad Layeghi	Oficemen	Spain
11569	47	8	47	8	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	Reject, we already use key references and the suggested article states 7.4 % without reference.	Haris Doukas	UNIVERSITY	Spain
11575	47	8	47	8	Please, add after Schneider 2019: "Sanjuán et al 2020". Please, add the following updated information: 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 "According to Sanjuán et al 2020, currently, cement production is considered as responsible for approximately 7.4% of the global carbon dioxide emission (2.9 Gtons in 2016)." 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	Reject, we already use key references and the suggested article states 7.4 % without reference.	Government of Saudi Arabia	UNIVERSITY	Spain
76505	47	9			Cement, Lime, and Plater production caused 2.87 Gt CO2e in 2015, accroding to my Nature Geoscience paper, https://doi.org/10.1038/s41561-021-00690-8. This is somewhere around 6% of GHG emissions (not permille), depending on what you include in the denominator.	Done	Cécile Seguineaud	Norwegian University of Science and Tech	Norway
3525	47	9	47	9	It should be % instead of %o.	Done	Tennant Reed	IECA	Spain
10415	47	9	47	9	It should be % instead of %o.	Thanks	Government of Canada	Oficemen	Spain
11571	47	9	47	9	It should be % instead of %o.	Thanks	Government of Canada	UNIVERSITY	Spain
29793	47	9	47	9	Please correct error. The number given should be percent not permille, as it stands now. IEA Energy Technology Perspectives 2020 (p 216) estimates the emissions from cement to be 2.4 GtCO2 in 2019 or 7 % of energy system emissions.	Done	Tennant Reed	Norwegian Environment Agency	Norway
3531	47	10	47	10	Please, add after Bataille 2020a: "Sanjuán et al 2020".	Done	Government of United States of America	IECA	Spain
10421	47	10	47	10	Please, add after Bataille 2020a: "Sanjuán et al 2020".	Reject, we already use key references and the suggested article states 7.4 % without reference.	Rebecca Dell	Oficemen	Spain
11577	47	10	47	10	Please, add after Bataille 2020a: "Sanjuán et al 2020".	Reject, we already use key references and the suggested article states 7.4 % without reference.	Cécile Seguineaud	UNIVERSITY	Spain
3527	47	11	47	11	calcium carbonate (limestone) decomposition into calcium oxide in cement kinls is done at 1000-1100°C, not at 850°C.	The reaction start at 848C - temperatures are higher later in the kiln.	Philippe Tulkens	IECA	Spain
10417	47	11	47	11	calcium carbonate (limestone) decomposition into calcium oxide in cement kinls is done at 1000-1100°C, not at 850°C.	Revised to 850 or higher	Government of United States of America	Oficemen	Spain
11573	47	11	47	11	calcium carbonate (limestone) decomposition into calcium oxide in cement kinls is done at 1000-1100°C, not at 850°C.	Revised to 850 or higher	Haris Doukas	UNIVERSITY	Spain
14997	47	14	47	16	I strongly support this draft. Please indicate additional references to further strengthen the paragraph. 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/p02hmc2l/ivl-report-co2-uptake-in-cement-containing-products-isbn-number-b2309.pdf	Added	Nikas Alexandros	Japan Cement Association	Japan
43961	47	14	47	18	Scientific research has indeed shown that concrete reabsorbs CO2 over its service life and that concrete is a carbon sink. The cement industry appreciates IPCC acknowledgement of this key characteristic of concrete and shows that with its durability and resilience, concrete is a true sustainable building material. Conservative estimates have shown that concrete can absorb 23% of the process CO2 emissions across its service life. Additional calculations will likely show that the percentage is significantly higher than 23%. While using CO2 as a hardening agent to dispose of CO2 is a technology that requires further research, it is inappropriate for IPCC to identify proprietary products, such as CarbonCure, in the report. However, if one considers the entire carbon footprint of the Carbon Cure C02, it is not clear that the net effect is beneficial with respect to CO2 reduction.	Agreed.	Philippe Tulkens	Portland Cement Association	United States of America
82777	47	14	47	16	consider citing cao et al. here regarding in-place concrete carbonation: https://doi.org/10.1038/s41467-020-17583-w	Done	Government of United States of America	Northwestern University	United States of America
3533	47	16	47	16	After "...(Schneider 2019)." , could you please 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	Added	Government of United States of America	IECA	Spain
10423	47	16	47	16	After "...(Schneider 2019)." , could you please 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	Word count prevents elaborating such detail	Constantinos Psomopoulos	Oficemen	Spain
11579	47	16	47	16	After "...(Schneider 2019)." , could you please 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	Word count prevents elaborating such detail	Government of United States of America	UNIVERSITY	Spain
82779	47	16	47	18	the main CO2 savings comes from reducing the need for binder, which should probably be stated explicitly here. Consider citing: https://doi.org/10.1088/1748-9326/ab466e	Added	Government of United States of America	Northwestern University	United States of America
3519	47	18	47	18	Add in line 18 the following paragraph: "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	noted	Philippe Tulkens	IECA	Spain
10409	47	18	47	18	Add in line 18 the following paragraph: "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	Word count prevents elaborating such detail	Government of United States of America	Oficemen	Spain
11565	47	18	47	18	Add in line 18 the following paragraph: "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	Word count prevents elaborating such detail	Philippe Waldteufel	UNIVERSITY	Spain
15869	47	19	47	20	expression is somewhat confusing to understand	Edited	Eric Masanet	KIET(KOREA INSTITUTE FOR INDUSTRIAL ECONOMICS & TRADE)	Republic of Korea

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
3539	47	20	47	20	Could you please replace "stronger cement through..." by "...stronger concrete through...".?	Edited	Government of United States of America	IECA	Spain
10431	47	20	47	20	Could you please replace "stronger cement through..." by "...stronger concrete through...".?	Edited	Célia Sapart	Oficemen	Spain
11587	47	20	47	20	Could you please replace "stronger cement through..." by "...stronger concrete through...".?	Edited	Christian Breyer	UNIVERSITY	Spain
57499	47	21			Reword "poorly and well made concrete can varying in strength by a factor of 4 for a given volume" to "poorly and well made concrete can vary in strength by a factor of 4 for a given volume".	Edited	Government of United States of America	U.S. Department of State	United States of America
85127	47	21	47	21	Correct "varying" to "vary"	Edited	Government of United States of America	Australian Industry Group	Australia
3521	47	24	47	24	After the line 24, could you please add the Figure 3 from the reference Sanjuán et al. 2016? In addition, the following paragraph could be added: "Figure 3 shows the results of the assessment for CO2 emissions reduction potential with regard to the implementation maturity and technical applicability." "Figure 3: Results of the assessment for CO2 emissions reduction potential - implementation maturity and technical applicability. " 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	Noted and rejected	JAE YOON LEE	IECA	Spain
10411	47	24	47	24	After the line 24, could you please add the Figure 3 from the reference Sanjuán et al. 2016? In addition, the following paragraph could be added: "Figure 3 shows the results of the assessment for CO2 emissions reduction potential with regard to the implementation maturity and technical applicability." "Figure 3: Results of the assessment for CO2 emissions reduction potential - implementation maturity and technical applicability. " 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	Noted and rejected	JAE YOON LEE	Oficemen	Spain
11567	47	24	47	24	After the line 24, could you please add the Figure 3 from the reference Sanjuán et al. 2016? In addition, the following paragraph could be added: "Figure 3 shows the results of the assessment for CO2 emissions reduction potential with regard to the implementation maturity and technical applicability." "Figure 3: Results of the assessment for CO2 emissions reduction potential - implementation maturity and technical applicability. " 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	Noted and rejected	Government of United States of America	UNIVERSITY	Spain
43963	47	26	47	30	I disagree with the statements that "[a]rchitects, engineers and contractors also tend to overbuild with cement because it is cheap, corrosion and water resistant" and "[b]uildings and infrastructure can be purposefully designed to minimize cement use to its essential uses (e.g., compression strength and corrosion resistance) and replace it with other materials (e.g., wood, stone, other fibres) for non-essential uses." This presents a false assumption that designers overbuild with concrete because concrete is cheap. Designers build based on demand and their choice of building material is certainly influenced by economic factors. I disagree that cement and concrete can be optimized in construction application. The report's assumption other materials (wood, stone, etc.) are preferable for nonessential uses is unfounded from both a lifecycle and performance perspective.	Fine, but lots of papers disagree. You need to substantiate your objection for us to use it.	Government of United States of America	Portland Cement Association	United States of America
82781	47	29	47	30	consider citing Shanks et al. here: How much cement can we do without? Lessons from cement material flows in the UK W Shanks, CF Dunant, MP Drewniok, RC Lupton... - Resources, Conservation and Recycling, 2019	Done	Government of United States of America	Northwestern University	United States of America
57501	47	32	47	32	Some companies are replacing limestone with other minerals in the kiln so that the resulting clinker is lower in CO2 emitted from the process side of cement making. This may be another strategy developing.	Reject since EE is often quite well represented in scenario modelling	Constantinos Psomopoulos	U.S. Department of State	United States of America
82783	47	35	47	35	replace "cementitious materials" with "supplementary cementitious materials" to align with common terminology; it might also be good here to state explicitly that some of these alkaline industrial wastes can be used for CO2 mineralization, so there is competition between the SCM and mineralization CCU levers that is important to understand	Done	Government of United States of America	Northwestern University	United States of America
43965	47	36	47	37	Not all clays are suitable as replacements for clinkers. Also, clays require processing to be used as clinker replacements.	Done	Government of United States of America	Portland Cement Association	United States of America
29795	47	39	47	39	Please add ".. where appropriate." at the end of this sentence. Regulation is in place to ensure the quality of infrastructure, and not all low-clinker cements are appropriate for all uses and climatic conditions.	Agreed, done.	Government of United States of America	Norwegian Environment Agency	Norway
29437	47	40	48	1	Consider adding information of an amine scrubber project on a cement plant. E.g. In Norway CCS fullchain CCS project “Longship” passed the final investment decision in 2020 and will be in operation in 2024. This project includes an amine scrubber technology on a cement plant capturing 400 000 tonnes CO2 pr. annum (ca. 360 000 tonnes fossil and 40 000 tonnes bio-CO2). Waste heat from the cement process is used as energy input to the amine process reducing additional energy input with appr. 75%. Source:(Norwegian government: Longship – Carbon capture and storage — Meld. St. 33 (2019–2020) https://www.regjeringen.no/contentassets/943cb244091d4b2fb3782f395d69b05b/en-gb/pdfs/stm201920200033000engpdfs.pdf and Gassnova SF: Developing Longship – Key lesson learned (2020) https://ccsnorway.com/project-outcomes/)	Noted, and edited where necessary	Changke WANG	Norwegian Environment Agency	Norway
43967	47	48	48	1	I agree that the different CCUS approaches have strengths and weaknesses concerning emissions abatement potential, primary energy consumption, costs, and retrofitability. It is important to emphasize that there is no "silver bullet" or "one size fits all" CCUS solution.	Noted, and edited where necessary	Tennant Reed	Portland Cement Association	United States of America
85129	47	48	47	48	Correct "strength" to "strengths"	Noted, and edited where necessary	Nikas Alexandros	Australian Industry Group	Australia
29797	48	2	48	2	Consider adding to this para, by including the possibility of negative emissions from cement production. For example: "Many cement kilns burns various amounts of waste for energy, some with high biomass content. Post-combustion CCS on such kilns will lead to some amounts of negative emissions (e.g. the Norcem Brevik project in Norway), with high capture rates such projects will be carbon negative."	Added	Government of France	Norwegian Environment Agency	Norway
14999	48	3	48	4	The following red text with the reference literature should be added at the head of the draft text; The cement industry currently utilizes waste fuels for clinker production by saving 15 up to 20% of traditional thermal energy consumption (Y. Izumi, 2014)* The energy-related emissions of cement production can also be reduced by using------. *: 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.	Unless the carbon content of the waste fuels is explicitly less, I cannot introduce this.	Government of Canada	Japan Cement Association	Japan
43229	48	3	48	4	This is not necessarily true. Using bioenergy for cement kilns runs into the same problems as using biofuels in other contexts -- it encourages deforestation and/or competes with food production for arable land. In fact, carbon neutral cement production has yet to be achieved outside of the lab and remains an important technological hurdle. Mamani-Soliz, P., Seidl, L. G., Keller, F., Lee, R. P., & Meyer, B. (2020). Chemisches Recycling - Aktueller Stand und neue Entwicklungen. In Recycling und Sekundär-Rohstoffe (Vol. 13). Seidl, L. G., Lee, R. P., Keller, F., & Meyer, B. (2020). Beitrag des chemischen Recyclings zur Defossilierung von Rohstoffketten. In Energie Aus Abfall (Vol. 17). TK.	This is handled in 11.3.6 and elsewhere.	Tennant Reed	Zero Waste Europe/University of Manchester	United Kingdom (of Great Britain and Northern Ireland)
43969	48	3	48	11	This statement that the LEILAC approach allows the potential electrification of the calciner is misleading. The LEILAC approach uses natural gas burners to indirectly heat the calciner vessel. I agree that electrification of the calciner vessel is a possibility but additional research, development, and innovation to provide economically practicable commercial technologies and a power grid capable of supporting such an energy intensive process are needed.	Edited for clarity.	Government of United States of America	Portland Cement Association	United States of America
82787	48	3	48	4	consider citing mitigation potential of bio-derived fuels from the IEA cement technology roadmap	Edited and otherwise included as a batch with other comments	Government of France	Northwestern University	United States of America
82791	48	4	48	4	consider discussing more the technology readiness of electrified or H2 kilns, which may be a long way off; look to IEA ETP 2020 for data	Edited and otherwise included as a batch with other comments	Government of Germany	Northwestern University	United States of America
29799	48	12	48	13	Please consider deleting or rephrasing this sentence. Post-combustion CCS in combination with some bioenergy use can "decarbonise" (reach net zero emissions) Portland cement production. If the sentence refers to some overall assessment of the practicality of using this option in all regions, please include a reference to this.	Edited and otherwise included as a batch with other comments	Tennant Reed	Norwegian Environment Agency	Norway
43971	48	12	48	16	Lower carbon cement chemistries are not nearly as widely available as limestone deposits, which is the primary reason that the lower carbon cement chemistries will remain niche products.	Edited and otherwise included as a batch with other comments	Government of France	Portland Cement Association	United States of America
82785	48	12	48	16	since there is much innovation happening in low-carbon cement chemistries and some important application limitations to some of them, it seems more elaboration on their types, development status, markets, and barriers is warranted here because policy makers are no doubt looking to these chemistries as potential solutions. more discussion is needed. consider the following sources for good reviews: https://www.chathamhouse.org/2018/06/making-concrete-change-innovation-low-carbon-cement-and-concrete and https://www.research-collection.ethz.ch/handle/20.500.11850/301843	Edited and otherwise included as a batch with other comments	louis lubango Mitondo	Northwestern University	United States of America
29801	48	13	48	16	Please consider other sources here. Material economics, 2019 concludes that there are strong limitations on alternative clinkers. For example, from page 173: "The chief limitation of alternative clinkers in a net-zero scenario is the extent of emissions reductions they offer and the limited availability of raw materials.", "Notably, alkali- and geopolymer-based cements could in principle eliminate nearly all process emissions, and cement based on magnesium silicate could eliminate them entirely, but the required minerals are not widespread."	Edited and otherwise included as a batch with other comments	Government of Germany	Norwegian Environment Agency	Norway
57503	48	17		21	Not just education, but codes, standards, certification, labeling, procurement, incentives, and a range of polices to help create the market will be needed, as well as those for information disclosure, and certification for quality.	Edited and otherwise included as a batch with other comments	Government of France	U.S. Department of State	United States of America
82789	48	17	48	18	The following sentence is too simplistic: "All the above, however, require comprehensive education and continuing re-education for cement producers, architects, engineers, contractors and small, non-professional users of cements." There is far more than education required. Emerging kiln techs will require huge capital investments and incentives for early replacement (kilns lifespans can be 20-30 yrs) at cement producers, more efficient designs will require changes to building codes, more CCS will require infrastructure investments, low-carbon chemistries will require new materials testing protocols, codes, pilots and demonstrations, etc. The closing statement should not imply that everything comes down to education, which is only one factor.	Edited and otherwise included as a batch with other comments	Government of France	Northwestern University	United States of America
76507	48	22	50		I miss a mentioning of concentrated solar power to drive industrial processes. See, e.g. https://doi.org/10.1016/j.rser.2017.08.065 https://doi.org/10.1016/j.solener.2018.05.085	Reference will be added	Cédric PHILIBERT	Norwegian University of Science and	Norway
82793	48	22	48	22	consider reviewing and integrating new data, categorization of levers, and technology readiness aspects for decarbonizing chemicals in IEA ETP 2020, which covers a lot of terrain that would be useful to synthesize into this section	Thanks, helpful comment. Will do	Government of Canada	Northwestern University	United States of America
69869	48	32	48	38	Bazanella and Ausfelder, 2017, op. cit., detail the exceptional efficiency of mechanical vapor recompression and its many uses in chemical industries.	Thanks, recompression should be mentioned	Matthias Honegger	Institut Français des Relations	France
78775	48	39	48	42	a most recent research by Fasihi et al. (2021. Global potential of green ammonia based on hybrid PV-wind power plants, Applied Energy, in press) shows that a full green ammonia supply is possible and beneficial, which may be the key to eliminate the CO2 emissions induced by the fossil gas related steam methane reforming process delivering the hydrogen in the present process, or even worse, coal-based as in China	Reference will be added	NAOKI AOKI	LUT University	Finland
85131	48	44	48	44	Correct "natural reforming with CCS" to "natural gas reforming with CCS"	Thanks	Philippe Tulkens	Australian Industry Group	Australia
84933	48		50		This section really needs a discussion of the social (in addition to the technological) options for improving recycling and retaining material value of plastics.	Thank you good suggestion	Government of France	ClimateWorks Foundation	United States of America
84935	48		50		This section also really needs a discussion of what chemical recycling is, what it means, what its energy requirements are, and why it entails significant carbon losses.	Argument will be clarified (energy use and thus carbon losses unless electrified)	Tennant Reed	ClimateWorks Foundation	United States of America

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
15561	49	23	49	24	Figure 11.11 difficult to read. Additional explanations above the figure would be welcome.	Figure will be replaced	Eric Masanet	MINES ParisTech, Total	France
46125	49	11	49	15	Please remove reference to chemical recycling. Suggested sentence: "Reducing life cycle emissions can partly be achieved by closing the material cycles (Figure 11.11) starting with material and product design planning for re-use, re-manufacturing, and recycling of products – ending with recycled feedstock that substitute virgin feedstocks for various chemical processes (Smet and Linder 2019; Rahimi and Garciá 2017)." Reasoning: Chemical recycling is not yet a standard state of the art technology and it's environmental benefit is not yet proven. (References: https://www.umweltbundesamt.de/sites/default/files/medien/5750/publikationen/hgp_chemischesrecycling_englisch_bf.pdf; https://www.vivis.de/wp-content/uploads/WM9/2019_WM_359-370_Quicker.pdf; https://www.nabu.de/imperia/md/content/nabude/abfallpolitik/zwe_jointpaper_understandingenvironmentalimpactsofcr_en.pdf)	Text will be revised to address social dimension of recycling, mechanical recycling but also keep chemical recycling as an emerging option.	louis lubango Mitondo	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety International Climate Policy	Germany
57505	49	11	49	11	In the documentary Manufactured Landscapes, waste plastics from North America computers (e.g., wire insulation) were incinerated in China with terrible local environmental results. Incineration of plastics may not be such a good idea or may require a lot of abatement measures.	Sentence already implies that incineration is a bad idea	Government of Canada	U.S. Department of State	United States of America
43227	49	19	49	21	There are no functioning examples of CCS for incinerators or cement kilns. This is speculative and should be removed.	The absence of functioning examples is not an argument for omitting this mitigation option	Government of United States of America	Zero Waste Europe/University of Manchester	United Kingdom (of Great Britain and Northern Ireland)
46127	49	25	49	27	Please delete second part of the caption: "which can handle any type of plastic waste (sorted or mixed) with close to 100% carbon recovery"; Reasoning: Chemical recycling is not yet a standard state of the art technology and it's environmental benefit is not yet proven. So far there is no chemical recycling plant using all kinds of input/any type of plastic. Those plants that exist use preferably quite clean plastic waste, mainly polyolefins without pollutions. The expected yield is far from 100% recycling rate. (References: https://www.umweltbundesamt.de/sites/default/files/medien/5750/publikationen/hgp_chemischesrecycling_englisch_bf.pdf; https://www.vivis.de/wp-content/uploads/WM9/2019_WM_359-370_Quicker.pdf; https://www.nabu.de/imperia/md/content/nabude/abfallpolitik/zwe_jointpaper_understandingenvironmentalimpactsofcr_en.pdf)	caption will be checked against original reference and caveats added on chemical recycling in the text	Mariel Vilella	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety International Climate Policy	Germany
43231	50	1	50	8	This is speculative and should be modified to reflect the fact that chemical recycling of plastics has yet to achieve commercial-scale operations. To date, chemical recycling operations suffer from high energy inputs, low yield, high CO2 emissions, and high levels of product contamination. As long as oil and gas provide cheap sources of feedstock, chemical recycling will be unable to compete economically. Sources: Rollinson & Oladejo 2020; Seidl et al. 2020; Mamani-Soliz et al. 2020. Ref: Rollinson, A., Oladejo, J. (2020). Chemical Recycling: Status, Sustainability, and Environmental Impacts. Global Alliance for Incinerator Alternatives. doi:10.46556/ONLS4535; Seidl., L.G., Lee, R.P., Keller, R.P., Meyer, B. 2020. Beitrag des chemischen Recyclings zur Defossilierung von Rohstoffketten – Konzeptstudie für die nachhaltige Olefinerzeugung in Deutschland. In Thiel, S., Thomé-Kozmiensky, E., Quicker, P., Gosten, A. (Hrsg.): Energie aus Abfall, Band 17, ThoméKozmiensky Verlag GmbH, pp. 115-137; Mamani-Soliz, P., Seidl, L, G., Keller, F., Lee, R.P., Meyer, B. 2020. Chemisches Recycling – Aktueller Stand und neue Entwicklungen. In Holm O., ThoméKozmiensky, E., Goldmann, D., & Friedrich, B. (Eds.) Recycling und Sekundärrohstoffe, Band 13, Thomé-Kozmiensky Verlag GmbH, pp. 268 – 284.	Language on chemical recycling will be rebalanced	Government of Kenya	Zero Waste Europe/University of Manchester	United Kingdom (of Great Britain and Northern Ireland)
46129	50	1	50	16	The option "synthetic naptha", produced from CO2 and H2 and for example used in an electrified steam cracker is missing (please see also https://www.umweltbundesamt.de/rescue , https://www.umweltbundesamt.de/en/topics/climate-energy/climate-protection-energy-policy-in-germany/rescue-resource-efficient-pathways-to-greenhouse#background).	Difficult to access report in German but section will be revised to clearly identify green synthetic HxCy as option (MeOH, naphta etc.)	Aniceto Zaragoza	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety International Climate Policy	Germany
70465	50	1	50	27	This section could benefit from clearer structure. The three options could be described as improved recycling, synthetic feedstock and biomass feedstock. The section on recycling could expand a bit more on the various recycling technologies and their relative strenghts and weaknesses. For example, recycling technologies can roughly be listed in order of decending efficiency and increasing robustness as follows: mechanical recycling, solvolysis, pyrolysis, gasification. These additions would create a more complete overview and would also give some guidance on when to apply which technology.	Thanks, yes this section will be revised considering clarity around options	PEDRO MORA PERIS	European Union (EU) - DG Research &amp	Belgium
15879	50	3	50	19	The technology of replacing raw materials through chemical conversion of biomaterials or through hydrogenation mentioned in the report has been commercialized only in some items, and when targeting numerous chemical products, technology development for commercialization should still be preceded.	See previous comment	Damien Lamy	KIET(KOREA INSTITUTE FOR INDUSTRIAL ECONOMICS & TRADE)	Republic of Korea
82795	50	33	50	33	A major gap in this chapter seems to be a more nuanced coverage of light industry, which is in fact a very heterogeneous category comprised of many smaller plants globally. While more focus on heavy industry is justified, one would expect some basic discussion here about which are the sectors considered "light," what are their trends, what are the major uses of energy (e.g., motors, boilers, furnaces, etc.), how can those end uses be decarbonized in relation to the major levers discussed for heavy industry, what are the challenges faced, etc. Some of these "light" industries like semiconductor manufacturing might indeed become more important in the future and are already important from a GHG perspective (e.g., process emissions from semiconductor chemicals). Leaving all of these things unmentioned creates a policy blind spot for a major industry segment that will not automatically decarbonize if the heavy industries do, and which can be an important source of jobs and well being in many parts of the world. This lack of coverage implicitly sends the message not to worry about light industry, which is the wrong message to send.	Section will be revised with this in mind but word limits does not allow much elaboration	Philippe Tulkens	Northwestern University	United States of America
69871	50	36	50	37	Madeddu et al. (op. cit.) point out that technologies currently under development would allow 99% electrification of industrial heat;	Thanks, this will be checked	Eleni Kaditi	Institut Français des Relations	France
69873	50	38	50	38	Direct solar heating is not limited to 100°C. Low-concentration non-imaging CPC technology allows to reach up to 200% in panel with no tracking device (see e.g. https://articsolar.com/advanced-high-temperature-solar-thermal-xcpc/). Concentrating solar technologies allow reaching temperatures of ~390°C in troughs and up to 1000°C in central receiver systems (heliostats and towers), not to mention the 3000°C reached in solar ovens. The largest solar thermal plants deployed is 350 MW heat for EOR in Oman, technology Glasspoint. Research and development is underway, for example, for running cement making and other non-metallic mineral processes with concentrated solar heat in towers with particulate receivers (EU-backed SolPART project undertaken by the CNRS and involving CEMEX, OCP Group and others).	Section will be revised	Paul Rouse	Institut Français des Relations Internationales	France
69875	50	39	50	39	Industrial heat-pumpts could technically deliver heat at temperatures as high as 400°C, based either on the reversed Brayton cycle or on the multi-stage steam compression cycle, although heat pumps delivering heat at temperatures up to 280°C would more likely prove cost-effective. See Zühlsdorf et al. 2019, Analysis of technologies and potentials for heat pump-based process heat supply above 150°C, Energy Conversion and Management, X2 100011	Reference will be added	Eve Tamme	Institut Français des Relations Internationales	France
69877	50	39	50	41	Several electric technologies can deliver equivalent service, such as steam flows at temperature of 1000°C or higher (based on conversion of variable electricity into constant heat flux with heat storage in refractory bricks), plasma torches, etc.	plasma torch option to be mentioned	Célia Sapart	Institut Français des Relations Internationales	France
69879	50	43	50	45	To avoid losing important energy amounts in low grade steam, mechanical vapour recompression is the most efficient technology.	Recompression to be added here and above	Sylvain Nizou	Institut Français des Relations	France
57507	51	1	51	1	Paradoxically, more secondary aluminum production would represent a movement away from electricity in this industry, because the Hall-Heroult process uses electricity to produce aluminum, and will use heat to melt down scrap, often from natural gas.	Reject: unless electricity is used for heating	Christian Breyer	U.S. Department of State	United States of America
57509	51	11	51	15	In Figure 11.12, separate primary and secondary production in the "global" boxes. It looks implied, but it should be explicit. Also, there's a big decline from manufacturing (last Global box) to use step that should be corrected, unless there's some reason that should exist.	Consider deleting this figure as it is not so important. Scraps from manufacturing indeed recycled	Tennant Reed	U.S. Department of State	United States of America
3709	51	12			in Fig 11.12, woud be better to have Mt expressed directly in grey forms. Also in some places (e.g. after refining, or production) the outflow does not equal inflow. where is the difference going ? after Use a large amount is lost, I suppose because the product is still used (as you mentioned, in windows or whatever)? should be made clearer when presenting the figure.	Figure is problematic and may be deleted	Arun kumar Nayak	Mines Saint-Etienne	France
76509	51	17	51	30	References are required to support those statements. I suspect the 1/20th energy use for recycling only refers to the melting energy, not the collection, transport, cleaning? Note that Al is not easier to melt than other metals, it just requires more energy for primary production.	Thank you. Reference will be added.	Arun kumar Nayak	Norwegian University of Science and Tech	Norway
57511	51	28			"Aluminium, if is not contaminated, is ..." should be "Aluminium, if not contaminated, is ..."	Thanks	Célia Sapart	U.S. Department of State	United States of America
3711	51	30			what do you mean by "not contaminated" ? as the outcomes of the paper is to find solutions, maybe it should be made clearer what is contaminated aluminium so we stop producing it because it wouldn't be recyclable in the end (I've seen something about soda cans that are barely recyclable because of the plastic film inside, or paintings outside). must be checked	Word count limits elaboration on types of contamination but we will look into this	Sylvain Nizou	Mines Saint-Etienne	France
76511	52	1	52	14	References required.	Agree	Christian Breyer	Norwegian University of Science and Tech	Norway
69881	52	1	52	2	Adapting aluminium smelters to variable renewable electricity flows is a challenge, however. Aluminimum is a very inflexible electricity customer for the "pots" would be deteriorated if the temperature signficantly deviates from its optimum value. Heat management has been shown an effective way to introduce greater flexibility in the electricity consumption of aluminium smelter at the Trimet plant in Essen, Germany, based on the New Zealand's Energia Potior process. See Philibert, 2017, op. cit., p. 20.	Reject. Word count does not allow this detail	Government of United States of America	Institut Français des Relations Internationales	France
57513	52	15			The chapter emphasizes that the pulp and paper industry is an energy-intensive industry (see page 52). However, as shown in Table 11.1, food and tobacco emit 77% more greenhouse gases than pulp and paper. The average annual growth rate of industrial greenhouse gas emissions in food and tobacco is much higher than that of paper and pulp, and its share of total industrial emissions is 75% greater than that of paper and pulp. Should the report focus on the food and tobacco industry, or at least explain why the report does not focus on this sector?	Thank you. This will be clarified. PoP is there due to large biogenic carbon emissions	Government of United States of America	U.S. Department of State	United States of America
1205	52	16	52	17	The sentence misses one of the primary feedstocks for pulp mills. Change the sentence to read, "The pulp and paper industry has pulp mills, integrated pulp and paper mills and paper mills using virgin pulpwood, residues and co-products from wood products manufacturing, and recycled paper as feedstock."	Actually also grass/bamboo/textile fibres.... Sentence will be revised	Eric Masanet	Private Consultant	United States of America
57515	52	16	52	26	It seems like Black Liquor Boilers and Steam Generation should be mentioned in this section. Black Liquor Boilers burn black liquor to concentrate and recover process chemicals. The thermal energy generated in the process is used to generate steam. Nominally, one-third of the mass of black liquor is carbon resulting in significant carbon dioxide emissions. The steam generated in the black liquor boilers is used in the pulp-and-paper making processes after generating power (nominally 60% of site needs) in steam turbines.	Agree	Tennant Reed	U.S. Department of State	United States of America
57517	52	18	52	19	Authors should mention the Kraft process somewhere; black liquor, a "renewable" waste product from the paper production process, is burned in recovery boilers that provide steam and electricity.	Agree	Government of United States of America	U.S. Department of State	United States of America
1207	52	24	52	24	Insert a new sentence after "...heat source." saying "To the extent that these technologies allow more efficient use of biomass, they make biomass available to displace fossil fuels elsewhere."	Elelctrification of P&P will be mentioned	Jeffrey Merrifield	Private Consultant	United States of America
72857	52	24	52	24	Suggestion replace "heat source" with "capable of delivering 150°C if provided with enough heat"	HTHP discussed elsewhere. Declined	Government of United States of America	EE-Consultant	France
57519	52	27	52	29	Authors should mention the necessity of replanting harvested trees. Trees are being cut down in the American South to provide pellets for European home heating. Many of these trees aren't being replaced.	Thank you. This point will be stressed here or somewhere else to underline the importance of sustainably produced biomass even if pellets for heating is not about PPI.	Maike Nicolai	U.S. Department of State	United States of America
70467	52	36	52	40	This section could be shortened to just the first sentence as the rest is not specific to the pulp and paper industry and is already more completely treated elsewhere.	Reject: will revise but sourcing of carbon from PoP is worth mentioning	Maike Nicolai	European Union (EU) - DG Research &amp	Belgium
47277	53	6	53	8	Specification of the geographical scope needed - are these generalizable conclusions? Also note that the 2050 timeline is not a golden standard, large subsectoral differences and timings for a net-zero objective exist along the 1.5C objective. See e.g. van Sluisveld et al (in review), the FORECAST or PRIMES scenarios published in EC (2018) van Sluisveld, M.A.E. and de Boer, H.S. and Daioglou, V. and Hof, A.F. and van Vuuren, D.P. (in review, minor revs and submitted before cutoff date) " A race to zero - assessing the position of heavy industry in a global net-zero CO2 emissions context" EC, 2018. In-depth analysis in support of the Commission Communication Com(2018) 773 - A clean planet for all, a European long-term strategic vision for a prosperous, modern, competitive and climate neutral economy	Noted	Government of United States of America	PBL Netherlands Environmental Assessme	Netherlands
57525	54	1			In Table 11.4, column 5, explain this column better and spell everything out. Make sure everything is denominated in dollars in this column to ease comparisons. No need to put USD in each table entry if in column label.	Edited	Government of Germany	U.S. Department of State	United States of America
57527	54	1			Year of what? Commercialized?	Edited	Government of Argentina	U.S. Department of State	United States of America
43025	54	1	54	1	In the header row, the fifth column from the left titled 'Breakeven Est (USD per tCO2 eq, %)' is suggested to be clearly defined, as the contents of that column seem to have varying units	Edited	Government of Argentina	Independent Researcher	India
43027	54	1	54	1	Suggest to clarify the scale on which TRL rating has been provided and the basis used for the same	NASA/IEA standard	Government of Argentina	Independent Researcher	India

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
46131	54	1	55	1	Green house gas reduction in the pulp and paper industry up to 99% by full biomass firing is by far overestimated. This is only possible for virgin pulp mills and integrated mills. While those mills are CO2 neutral already nowadays, recycled fibre processing mills use only up to 20% alternative fuels (like fibres sludge, deinking sludge, biogas, sorting residues). To increase circularity, it will not be possible to substitute all the fossil fuels of the paper industry with biomass. In Germany the share of waste paper of the fibres used for the production of paper is already 75%. Proposed change: reduce the potential of green house gas reduction in the pulp and paper industry to 60-75% by full biomass firing. Please see also for energy demand of the pulp and paper production: https://eippcb.jrc.ec.europa.eu/reference/production-pulp-paper-and-board; https://www.iea.org/reports/pulp-and-paper; https://www.umweltbundesamt.de/publikationen/germany-in-2050-a-greenhouse-gas-neutral-country, chapter pulp and paper industry	Edtied, thank you.	Government of Argentina	Federal Ministry for the Environment, Nat	Germany
82797	54	1	55	1	it would be good to explain more how the mitigation potentials should be interpreted, i.e., are they additive, multiplicative, and/or presented in isolation with overlaps; also, any means of linking the various mitigation strategies presented here back to the terms of the kaya identity would be helpful, since the relationship between the kaya framing and the opportunities and numbers presented has been getting weaker in the second half of the chapter	Noted for final rewrite	Government of Argentina	Northwestern University	United States of America
2265	54	1	56	1	Throughout the Table 11.4, "?" Should be further explained	Done	Government of Argentina	Hongik University	Republic of Korea
16565	54	1	56	1	Throughout the Table 11.4, "?" Should be further explained	Done	Government of Argentina	Korea Meteorological Administration (KM	Republic of Korea
57521	54	1	56	1	In Table 11.4, add energy efficiency measures for each sector. They will most likely be net negative cost and available "today". Within sectors, list measures by the year they are available so that they start with those available today and then move into the future.	These have been handled in other sections where the material to deep reducitons. We will place EE in context in teh final reqrite	Government of Argentina	U.S. Department of State	United States of America
57523	54	1	56	1	For Table 11.4, Technological potentials and costs for deep decarbonisation of basic industries, make sure to consult the technology database maintained by DEEDS (https://deeds.eu/results/industry-database/).	Noted, thank you, we will do this if extra time presents itself.	Government of Argentina	U.S. Department of State	United States of America
85133	54	1	56	1	Table 11.4 is excellent and useful. It would be great to find a way to add information on how commonly each mitigation option identifed is including in Integrated Assessment Models and sector-specific models.	Thank you. We have been talking about this, and are challenged with how to do it.	Government of Argentina	Australian Industry Group	Australia
3713	54				GHG reduction percentages should be explained as reduction per technology in the corresponding field, otherwise, one may not understand why the sum goes beyond 100%. also, having values for each (or almost all) cell in Current Column would be a plus	Title edited to include that the %s are multiplicative	Célia Sapart	Mines Saint-Etienne	France
43929	54				Table 11.4 Iron and steel, the breakeven est. for Material efficiency is "Subject to supply chain building codes and education", not all iron and steel are used for building, building codes are a factor, but not for all material efficiency related masures. The breakeven Est. are also subject to factors such as manufacturing costs and technology options.	See sector sections	Christian Breyer	Yale University	United States of America
43931	54				Table 11.4 Iron and steel, the breakeven est. for more recycling is "Subject to logistical costs", logistical costs is just one cost components of recycling, the capital investment and operational costs of recycling processes themselve (no matter chemical or mechanical recycling) are large parts of costs, which should be included here.	See sector sections	Maike Nicolai	Yale University	United States of America
43973	54				Up to 24% reduction by 2025 from building design choices is unrealistic due to the issue that there is the building code cycle. Clinker substitution of 40-50% today seems really ambitious, certainly in the U.S. The issue of lower clinker substitution in the U.S. is institutional inertia and market barriers to using blended cements, including portland-limestone cement (PLC). Reductions of 75% just from aggregate optimization also seems really ambitious due to the issue of aggregate availability.	These are literature value of best available practice	Government of Germany	Portland Cement Association	United States of America
84937	54		55		Why doesn't this table include any reference to high-value recycling of steel (e.g. vacuum distillation to remove Cu)?	Vaccum distillation of molten steel to remove Cu is an ultra low TRL technology.	Government of Germany	ClimateWorks Foundation	United States of America
72859	54		56		The table 11.4 is wellcome and could be annouced already at the beginning of the reading page 45.	It's there, right after the start of 11.4	Government of Germany	EE-Consultant	France
57529	55	1			In Table 11.4, "Catalysis of olefins from (m)ethanol" entry, is 9% carbon reduction (column 3) a typo?	Under investigation as of August 12 2021		U.S. Department of State	United States of America
43933	55				Table 11.4 Chemicals, Electrocatalysis. Does the capital E represent energy cost?	Electricity. Thank you for showing this wasn't clear.	Government of Argentina	Yale University	United States of America
3715	56	2			several values are not known in columns, if not existing, perhaps this should be said in the text to drive researches towards these parts ?	Noted.		Mines Saint-Etienne	France
39081	56	5	56	11	Suggest to provide case studies that discuss about countries across the globe rather than focus on just UK, as the abatement costs for UK will hardly be representative or even close to the costs in the developing countries and may be misleading	I agree, but this is a characteristic of the literature, it is almost all UK or European..		Independent Researcher	India
57531	56	6	56	11	Convert GBP to USD (there are three places where there are GBP values).	No, the source literature is in GBP, we don't have basis for USD conversion.		U.S. Department of State	United States of America
57533	57	11	57	11	Euros used on this line. Settle on what currency you're using and use consistently throughout the document.	The source literature is in these values.		U.S. Department of State	United States of America
39079	57	15	57	17	Suggest to rephrase as 'For customers of final products, information on the potential impact of supply side decarbonization on final prices may be more useful than that of CO2 abatement costs"	Used, thank you.		Independent Researcher	India
52557	57	16	57	26	The discussion of carbon pricing in industry purports that having a carbon price will increase production costs but have a small effect on consumer prices. Rootzen and Johnsson (2016, 2017), which are used as support, do say the cost increases for end-consumers of a carbon price on the supply-side are rather small; but they make these claims looking at just one aspect of car manufacturing or building construction. For example, they say that if a carbon price of 100 euro/tCO2 is only applied to steel, then the price of a typical car rises by 0.5%. That does not mean if a carbon price is collectively applied to the manufacturing of *multiple* inputs of a car (petrochemicals/polymers, aluminum, steel, electricity generation, etc.), that the final price will only rise by a small amount. This part of the report and the corresponding section of the SPM (p. SPM-23, lines 45-46) need to be re-examined.	This is true, but by far the most GHG intensity in products and buildings is in energy use, steel, cement and chemical feedstocks.		Sustainability Advisor to the Minister Ministry of Petroleum and Mineral Resources	Saudi Arabia
43975	57	17	57	27	The report provides no justification that increases in cement costs do not impact housing costs. Construction costs for any structure are heavily dependent upon a variety of factors including the availability of labor and material. That availability includes, but is certainly not limited to, the supply and demand within particular market segments of labor (skilled, unskilled, transient, permanent, etc.), construction market segments (residential, commercial, institutional, industrial, etc.), and location (urban, rural, developed, undeveloped, etc.).	This is referenced by Rootzen and Johnsen 2016 for steel and 2017 for cememt		Portland Cement Association	United States of America
70469	57	17	57	39	Consider merging these two paragraphs and shortening the result. Some points are made in both paragraphs (eg the retail price of a car rises by ~0,5% due to higher prices for carbon neutral steel.	Done, thank you.		European Union (EU) - DG Research &amp	Belgium
39071	57	20	57	21	Suggest to remove the word 'only' because the intent is to inform the reader and let her/him assess whether 0.5% is small or large in quantum	Edited as a block		Independent Researcher	India
39069	57	21	57	23	The statement about the impact of decarbonization on prices being small, seems like a blanket statement (with high confidence), which has a weak basis and limited supporting data. The statement may convey the wrong idea that industries don't fully pass the cost increases to the customer. Suggest to either add supporting data or reduce the confidence of the statement by rephrasing	Edited as a block		Independent Researcher	India
43021	57	21	57	23	The statement about the impact of decarbonization on prices being small, seems like a blanket statement (with high confidence) for all consumers, which has a weak basis and limited supporting data. The statement may convey the wrong idea that industries don't fully pass the cost increases to the customer. Suggest to either add supporting data or reduce the confidence of the statement by rephrasing	Edited as a block		Independent Researcher	India
39073	57	25	57	27	Suggest to remove the word 'only' because the intent is to inform the reader and let her/him assess whether 0.2% is small or large in quantum	Edited as a block		Independent Researcher	India
39075	57	28	57	29	Suggest that the argument that first movers could be pushed out of business could be supported with empirical data	Edited as a block		Independent Researcher	India
28473	57	34	57	36	The statement is made from untraceable source. This source is peer-reviewed and finds that the price of a house would increase by around 1%: https://doi.org/10.1080/14693062.2016.1191007 This reflects the wider issue mentioned above with regards to the ETC.	Edited as a block		Bellona Europa	Belgium
39077	57	35	57	35	Suggest to remove the word 'only' because the intent is to inform the reader and let her/him assess whether 10-30% is small or large in quantum	Edited as a block		Independent Researcher	India
3717	57	37	57	38	remove s to evaluates. if they are two researchers working on the topic, same for concludes.	Edited as a block		Mines Saint-Etienne	France
39067	57	40	57	41	The argument about acceptability of price impact across significant share of customers in the value chain is suggested to be supported by evidence such as any studies/surveys related to willingness to pay (conducted for various stakeholders in the value chain).	Edited as a block		Independent Researcher	India
72861	57	40	57	44	The paragraph applies to price signals with seemingly individual consumers when most of the chapter is for "business to business" goods. Maybe precis it ?	Edited as a block		EE-Consultant	France
57535	57	45	58	22	Why is Box 11.2 here? Shouldn't it be in the section above on Chemicals?	Noted		U.S. Department of State	United States of America
43233	58	10	58	12	Overall, this box is very good, although it should also mention other impacts of plastic: ubiquitous pollution, disruption of marine foodwebs, contamination of food sources and drinking water, and public health impacts. Also, the conclusion needs to be strengthened: there is no way to reconcile predicted or even steady-state plastic production with necessary emissions reductions. Absolute reductions in plastic production are required. References: Azoulay, D., Villa, P., Arellano, Y., Gordon, M., Moon, D., Miller, K., & Thompson, K. (2019). Plastic & Health: The Hidden Costs of a Plastic Planet. Center for International Environmental Law. Retrieved from https://www.ciel.org/plasticandhealth/ Chemistry can help make plastics sustainable — but it isn't the whole solution. (2021). Nature, 590(7846), 363–364. https://doi.org/10.1038/d41586-021-00391-7 Hamilton, L. A., Feit, S., Kelso, M., Rubright, S. M., Bernhardt, C., Schaeffer, E., et al. (2019). Plastic & Climate: The Hidden Costs of a Plastic Planet. Center for International Environmental Law. Retrieved from https://www.ciel.org/plasticandclimate/ Zheng, J., & Suh, S. (2019). Strategies to reduce the global carbon footprint of plastics. Nature Climate Change, 9(5), 374–378. https://doi.org/10.1038/s41558-019-0459-z	The Box is about plastics and climate change and although we agree in principle we cannot go into all aspects of plastics. Low recycling rates, relevant to emissions, are now mentioned.		Zero Waste Europe/University of Manchester	United Kingdom (of Great Britain and Northern Ireland)
57537	58	13		22	Should this part be a part of the sub-sectoral assessment before Section 11.4.1.4?	We prefer to keep the section here in order to provide a coherent story on plastics and climate change.		U.S. Department of State	United States of America
82799	59	1	59	1	Section 11.4.2.1 this section didn't strike me as particularly useful, since the authors state it isn't possible to dissect the various scenarios to explain their differences in a meaningful way. For example, it would be useful to bin the results based on which studies relied on CCS above some threshold, which scenarios considered hydrogen for industry, which considered ME, etc. so that some patterns emerge that can reinforce key points made in the chapter. Instead, all the reader can really glean is that there is huge variation in what the scenarios accomplish w/ no deeper understanding of what distinguishes them from one another. Section 11.4.2.2 seems more useful for understanding elements of deep decarbonization scenarios, since it attempts to unpack and explain differences in more detail for a few key studies. Consider either eliminating 11.4.2.1 or attempting to further analyze the scenario pool for more meaningful messages?	rejected: as the reviewer says in 11.4.2.2 a more detailed discusson about the differences between the scenarios takes place incliding the drivers for specific results. The role of the short introductory section 11.4.2.1 is just a to make a short reference to the big scenario world and show the huge variety of potential futures for the sector		Northwestern University	United States of America
45591	59	7	59	11	What are all these dots in the picture? Individual outliers? Why are then energy intensities increasing so much in some of the scenarios?	accepted: dots will be eliminated in the final draft; energy intensity decreases through technology progress, change of processes etc (portfolio discussed in sections before)		Delft University of Technology	Netherlands
3719	59	21	59	21	they are -> there are ?	accepted		Mines Saint-Etienne	France
70471	60	1	61	15	Figure 11.14 and the accompanying text contain many abbreviations that are not explained. Without understanding the abbreviations, the text cannot be properly understood.	accepted: will be improved		European Union (EU) - DG Research &amp	Belgium

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
57539	60	9	61	6	These graphs need a better description of the scenarios. Without knowing what the curves represent, it's hard to understand or appreciate what they mean or the point the authors are trying make. Unless a reader is deeply familiar with the code names for curves and what they represent, they are hard to comprehend. So either create a summary or discuss what the ranges of scenarios represent. Otherwise, to most readers, Figure 11.4 is not informative.	accepted: will be improved		U.S. Department of State	United States of America
2267	60	11	60	12	The table have no legend(subjects)., Additional explanation for each lines in the figure should be suggested.	accepted: will be improved		Hongik University	Republic of Korea
16567	60	11	60	12	The table have no legend(subjects)., Additional explanation for each lines in the figure should be suggested.	accepted: will be improved		Korea Meteorological Administration (KM	Republic of Korea
57541	60	11	60	12	Does current policy energy use occur as a result of very low growth or declining GDP? Make that clear.	Rejected: I do not get the point; scenario are based on typical if-when relations, current policyin this context iss set as an assumption (if-condition)		U.S. Department of State	United States of America
57543	60	11	60	12	The legend needs to explain each line. For example, what does "CurPol" mean?	accepted: will be improved		U.S. Department of State	United States of America
57545	60	11	61	4	The key for the lower part of Figure 11.4 is missing some of the scenarios (e.g., the 1.5 scenarios). The scenario names should be fully written out in the caption.	accepted: will be improved		U.S. Department of State	United States of America
3721	61	5			There are lot of abreviations in the text. in Fig 11.14 it is starting to be difficult follow all of them. a small reminder of all the abreviations would be appreciable.	accepted: will be improved		Mines Saint-Etienne	France
3723	61	6			shows	accepted: will be improved		Mines Saint-Etienne	France
57547	61	6	61	8	">2NBZ" should be "<2NBZ"	accepted: will be improved		U.S. Department of State	United States of America
57549	61	8	61	8	"1.SSP and 1.SLD" should be "1.5SP and 1.5LD"	accepted: will be improved		U.S. Department of State	United States of America
72863	61	9	61	10	The sentence is difficult to understand	accepted: will be improved		EE-Consultant	France
3725	61	12			a steep	accepted: will be improved		Mines Saint-Etienne	France
72865	61	15	61	15	Cannot see 1.5Ren in the 11.14 figure	accepted: will be improved		EE-Consultant	France
57551	61	17	72	24	Section 11.4.2.2 is well-written, easy to follow, informative, and well-referenced. The comparison of the various IEA scenarios is appreciated.	Accepted: Thank you for the positive feedback		U.S. Department of State	United States of America
57553	61	17			The discussion about various versions of the IEA pathways is a little confusing and lengthy. Could this part be simplified to make the key takeaway message more clear?	Accepted: tried to condense the comparison		U.S. Department of State	United States of America
78777	61	17	72	24	it may be worth mentioning that in a first of its kind study it had been possible for Bogdanov et al. (https://www.sciencedirect.com/science/article/pii/S0306261920316639) to present an energy-industry transition based on full 100% renewables in hourly resolution and a technology-rich portfolio, which described industry in detail for cement, steel, chemicals and aluminum - finally on a full electricity basis (with direct but also indirect electrification) and a full set of synthetic fuels and chemicls (H_2, CH_4, Fischer-Tropsch fuels including naphtha, methanol, ammonia).	Accepted: reference (Bogdanov et al) will be added		LUT University	Finland
47311	61	22	62	12	Not sure if trying to be complete - but it's a very random selection of regional /global studies that are continuously recited throughout the text. Perhaps it is of use to make an overview of the available studies, and structure them according to (1) geographical scope (2) sectoral scope and (3) discipline or type of research, in a similar fashion as the 'pool analysis' of CH.3. It would be valuable to see who dominates the discoure of (specific) decarbonisation pathways for specific industries. More recent (academic) but unmentioned studies (with regional specification): Napp, T.A., Few, S., Sood, A., Bernie, D., Hawkes, A., Gambhir, A., 2019. The role of advanced demand-sector technologies and energy demand reduction in achieving ambitious carbon budgets. Applied Energy 238, 351-367. van Sluisveld, M.A.E. and de Boer, H.S. and Daioglou, V. and Hof, A.F. and van Vuuren, D.P. (in review, minor revs and submitted before cutoff date) " A race to zero - assessing the position of heavy industry in a global net-zero CO_2 emissions context"	Accepted: scenarios have been selected that provide a reassonable level of detail for discussion; there is no intention to spot the all scenarios, rather to be illustrative. The two mentioned reeferences will be checked and included.		PBL Netherlands Environmental Assessme	Netherlands
47279	62	13	62	14	Also note that this is also an artefact of different assumptions about timing and stringency of how climate policy is interpreted. This is not an apples-apples comparison statement.	Accepted: text will be adapted accordingly		PBL Netherlands Environmental Assessment Agency	Netherlands
3727	62	23			emissions	Accepted		Mines Saint-Etienne	France
15871	62	32	62	32	parentheses for RTS might be needed	Accepted		KIET(KOREA INSTITUTE FOR INDUSTRIAL E	Republic of Korea
80683	63	3	63	6	BECCS is not carbon neutral or negative in the near-term because it creates a carbon deficit for many years, generally several decades to a century. Danielle Venton, Core Concept: Can bioenergy with carbon capture and storage make an impact?, PNAS (2016); Leturcq, P. (2020) GHG Displacement Factors of Harvested Wood Products: the Myth of Substitution, Nature Scientific Reports 10:1–9; Mary S. Booth, Not carbon neutral: Assessing the net emissions impact of residues burned for bioenergy, Environ. Res. Lett. 13 (21 February 2018); Sterman J. D., et al. (2018) Does replacing coal with wood lower CO_2 emissions? Dynamic lifecycle analysis of wood bioenergy, Envtl. Research Letters 13(015007):1–10, 1 ("We simulate substitution of wood for coal in power generation, estimating the parameters governing NPP and other fluxes using data for forests in the eastern US and using published estimates for supply chain emissions. Because combustion and processing efficiencies for wood are less than coal, the immediate impact of substituting wood for coal is an increase in atmospheric CO_2 relative to coal. The payback time for this carbon debt ranges from 44–104 years after clear-cut, depending on forest type—assuming the land remains forest. Surprisingly, replanting hardwood forests with fast-growing pine plantations raises the CO_2 impact of wood because the equilibrium carbon density of plantations is lower than natural forests. Further, projected growth in wood harvest for bioenergy would increase atmospheric CO_2 for at least a century because new carbon debt continuously exceeds NPP. Assuming biofuels are carbon neutral may worsen irreversible impacts of climate change before benefits accrue. Instead, explicit dynamic models should be used to assess the climate impacts of biofuels."). Furthermore, even if BECCS were net zero or negative in the relevant next couple of decades, which it is not, large-scale biodiversity development requires vast land-use changes, which may have significant implications for food security and biodiversity. National Academies of Sciences, Engineering, and Medicine, Negative Emissions Technologies and Reliable Sequestration: A Research Agenda,10 (2019) ("Because food demand is expected to double by mid-century, repurposing a significant amount of current agricultural land to produce feedstocks for BECCS or for afforestation/reforestation might have a significant effect on food availability and food prices, with far-reaching effects on national security and biodiversity."). The IPCC Special Report on Climate Change and Land warns that high implementation of BECCS (11.3 GtCO_2 yr-1 in 2050) could increase the population at risk of hunger by up to 150 million people and could have significant impacts on desertification and land degradation. IPCC, Summary for Policymakers, In: Climate Change and Land: an IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems, 27 (2019) ("Impacts on adaptation, desertification, land degradation and food security are maximum potential impacts, assuming carbon dioxide removal by BECCS at a scale of 11.3 GtCO_2 yr-1 in 2050, and noting that bioenergy without CCS can also achieve emissions reductions of up to several GtCO_2 yr-1 when it is a low carbon energy source {2.6.1; 6.3.1}. Studies linking bioenergy to food security estimate an increase in the population at risk of hunger to up to 150 million people at this level of implementation {6.3.5}. The red hatched cells for desertification and land degradation indicate that while up to 15 million km2 of additional land is required in 2100 in 2°C scenarios which will increase pressure for desertification and land degradation, the actual area affected by this additional pressure is not easily quantified {6.3.3; 6.3.4}."). Using BECCS to draw down between 2 and 10 Gt CO_2 annually would require the dedication of land equivalent to the size of India, and possibly even double this amount, to support biomass production, introducing daunting logistical issues. Anderson K. & Peters G., The Trouble with Negative Emissions, Science 354:182–183 (2016) ("Moreover, the scale of biomass assumed in IAMs—typically, one to two times the area of India—raises profound questions about carbon neutrality, land availability, competition with food production, and competing demands for bioenergy from the transport, heating, and industrial sectors. The logistics of collating and transporting vast quantities of bioenergy—equivalent to up to half of the total global primary energy consumption—is seldom addressed. Some studies suggest that BECCS pathways are feasible, at least locally, but globally there are substantial limitations. BECCS thus remains a highly speculative technology."). BECCS also faces infrastructure-based limits from the lack of suitable long-distance biomass and CO_2 transport. Baik E. et al., Geospatial Analysis of Near-term Potential for Carbon-negative Bioenergy in the United States, Proc. Nat'l. Acad. Sci. 115(13):3290–3295 (2018) ("Previous BECCS deployment assessments have largely overlooked the potential lack of spatial colocation of suitable storage basins and biomass availability, in the absence of long-distance biomass and CO_2 transport. These conditions could constrain the near-term technical deployment potential of BECCS due to social and economic barriers that exist for biomass and CO_2 transport...If the total biomass resource available in the United States was mobilized for BECCS, an estimated 370 Mt CO_2·y−1 of negative emissions could be supplied in 2020. However, the absence of long-distance biomass and CO_2 transport, as well as limitations imposed by unsuitable regional storage and injection capacities, collectively decrease the technical potential of negative emissions to 100 Mt CO_2 ·y−1."). Moreover, large-scale BECCS could put significant strains on global freshwater use, biosphere integrity, and biogeochemical flows. Heck V. et al., Biomass-based Negative Emissions Difficult to Reconcile with Planetary Boundaries, Nature Climate Change 8:151–155 (2018) ("[W]hile large-scale BECCS is intended to lower the pressure on the [planetary boundaries (PB)] for climate change, it would most likely steer the Earth system closer to the PB for freshwater use and lead to further transgression of the PBs for land-system change, biosphere integrity and biogeochemical flows.").	Rejected: this is a general aspect highlighting the complex CO_2 emission balance for BECCS. This is discussed in other chapters, in this sectin we just explain the underlying results of the scenario studies an do not have the chance to add background information and present general caveats with regard to specific techologies.		Institute for Governance & Sustainable Development	United States of America
80683	63	3	63	6	Because of its many adverse consequences, bioenergy raises environmental justice issues. Wood pellet production facilities are often located in communities of color and environmental justice communities. Purifoy D., How Europe's Wood Pellet Appetite Worsens Environmental Racism in the South (5 October 2020) ("From Northampton County to Alabama's Black Belt, residents and activists say companies such as Enviva exploit mostly communities of color with promises to build up busted local economies with a "green energy" industry. Instead, communities hosting wood pellet facilities are not only further burdened by pollution and other local dangers, they are also entangled in yet another climate damaging trend — the destruction of biodiverse hardwood forests and the rise of monoculture tree plantations to produce energy that appears to pose climate threats similar to coal."). The production process releases harmful pollutants into the air and increases noise pollution, while the harvesting decreases biodiversity in the surrounding areas. Danielle Purifoy, How Europe's Wood Pellet Appetite Worsens Environmental Racism in the South (5 October 2020) ("Northampton County residents such as Joyner are more immediately concerned about the acute impacts of wood pellet manufacturing, from local clear cutting of privately owned forests to the 24/7 production process. […] In addition to the noise from grinding trees and truck traffic, Alston and others complain about a constant cloud of dust flowing from the plant onto their homes, cars, gardens and into their lungs. "); Environmental Integrity Project (26 April 2018), Dirty Deception: How the Wood Biomass Industry Skirts the Clean Air Act, 4-5 ("[Environmental Integrity Project's] survey reveals that these facilities emit dangerous amounts of air pollution, and further finds that state agencies consistently fall well short of their duty to ensure that these facilities control their pollution to the levels required by law, frequently due to misleading information supplied by the industry. As a result, many large pellet mills have been allowed to emit air pollution, especially volatile organic compounds (VOCs) and hazardous air pollutants at levels well above legal limits for years at a time."). These harms occur while the industry is falling short of its proposed climate and job goals. Note the environmental movement backlash against BECCS. See Anderson K. & Peters G. (2016) The trouble with negative emissions, SCIENCE 354:182–183. Even if BECCS were net zero or negative in the relevant next couple of decades, which it is not, CCS has not been perfected at scale nor has it received social acceptability. Governance gaps also exist. See Climate Geoengineering Governance Initiative (C2G2), Governing large-scale carbon dioxide removal: are we ready? (2018); Gregory Nemet et al., Negative emissions—Part 3: Innovation and upscaling, Environ. Res. Lett. (May 2018); European Academies Science Advisory Council, Negative emission technologies: What role in meeting Paris Agreement targets? (Feb 2018) ("CCS plans in Europe have been shelved so that whatever experience is being gained globally is outside Europe. The loss in momentum in implementing CCS technologies not only has serious implications for mitigation pathways, but also one of the most commonly cited NETs [negative emissions technologies] (BECCS) assumes the availability of cost effective 'off-the shelf' CCS, while another (direct air capture) relies on the widespread availability of CO_2 storage. At present, economic incentives for deploying CCS are inadequate (whether through the very low carbon price or targeted government support), while those for NET development are lacking."); Andersen & Peters, The Trouble with Negative Emissions, Science (Oct 2016). One study estimates that current rate of increase in CCS is 100 times lower than needed to meet the 2C target. See Haszeldine et al. (April 2018), Negative emissions technologies and carbon capture and storage to achieve the Paris Agreement commitments, Philosophical Transactions of the Royal Society.				

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80827	63	3	63	6	BECCS is not carbon neutral or negative in the near-term because it creates a carbon deficit for many years, generally several decades to a century. Danielle Venton, Core Concept: Can bioenergy with carbon capture and storage make an impact?, PNAS (2016); Leturcq, P. (2020) GHG Displacement Factors of Harvested Wood Products: the Myth of Substitution, Nature Scientific Reports 10:1–9; Mary S. Booth, Not carbon neutral: Assessing the net emissions impact of residues burned for bioenergy, Environ. Res. Lett. 13 (21 February 2018); Sterman J. D., et al. (2018) Does replacing coal with wood lower CO2 emissions? Dynamic lifecycle analysis of wood bioenergy, Envtl. Research Letters 13(015007):1–10, 1 ("We simulate substitution of wood for coal in power generation, estimating the parameters governing NPP and other fluxes using data for forests in the eastern US and using published estimates for supply chain emissions. 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IPCC, Summary for Policymakers, In: Climate Change and Land: an IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems, 27 (2019) ("Impacts on adaptation, desertification, land degradation and food security are maximum potential impacts, assuming carbon dioxide removal by BECCS at a scale of 11.3 GtCO2 yr-1 in 2050, and noting that bioenergy without CCS can also achieve emissions reductions of up to several GtCO2 yr-1 when it is a low carbon energy source {2.6.1; 6.3.1}. Studies linking bioenergy to food security estimate an increase in the population at risk of hunger to up to 150 million people at this level of implementation {6.3.5}. 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Heck V. et al., Biomass-based Negative Emissions Difficult to Reconcile with Planetary Boundaries, Nature Climate Change 8:151–155 (2018) ("[W]hile large-scale BECCS is intended to lower the pressure on the [planetary boundaries (PB)] for climate change, it would most likely steer the Earth system closer to the PB for freshwater use and lead to further transgression of the PBs for land-system change, biosphere integrity and biogeochemical flows.").	rejected: some comment as in line 823		Institute for Governance & Sustainable Development	United States of America
80827	63	3	63	6	Because of its many adverse consequences, bioenergy raises environmental justice issues. Wood pellet production facilities are often located in communities of color and environmental justice communities. Purifoy D., How Europe's Wood Pellet Appetite Worsens Environmental Racism in the South (5 October 2020) ("From Northampton County to Alabama's Black Belt, residents and activists say companies such as Enviva exploit mostly communities of color with promises to build up busted local economies with a "green energy" industry. Instead, communities hosting wood pellet facilities are not only further burdened by pollution and other local dangers, they are also entangled in yet another climate damaging trend — the destruction of biodiverse hardwood forests and the rise of monoculture tree plantations to produce energy that appears to pose climate threats similar to coal."). The production process releases harmful pollutants into the air and increases noise pollution, while the harvesting decreases biodiversity in the surrounding areas. Danielle Purifoy, How Europe's Wood Pellet Appetite Worsens Environmental Racism in the South (5 October 2020) ("Northampton County residents such as Joyner are more immediately concerned about the acute impacts of wood pellet manufacturing, from local clear cutting of privately owned forests to the 24/7 production process. […] In addition to the noise from grinding trees and truck traffic, Alston and others complain about a constant cloud of dust flowing from the plant onto their homes, cars, gardens and into their lungs. "); Environmental Integrity Project (26 April 2018), Dirty Deception: How the Wood Biomass Industry Skirts the Clean Air Act, 4-5 ("[Environmental Integrity Project's] survey reveals that these facilities emit dangerous amounts of air pollution, and further finds that state agencies consistently fall well short of their duty to ensure that these facilities control their pollution to the levels required by law, frequently due to misleading information supplied by the industry. As a result, many large pellet mills have been allowed to emit air pollution, especially volatile organic compounds (VOCs) and hazardous air pollutants at levels well above legal limits for years at a time."). These harms occur while the industry is falling short of its proposed climate and job goals. Note the environmental movement backlash against BECCS. See Anderson K. & Peters G. (2016) The trouble with negative emissions, SCIENCE 354:182–183. Even if BECCS were net zero or negative in the relevant next couple of decades, which it is not, CCS has not been perfected at scale nor has it received social acceptability. Governance gaps also exist. See Climate Geoengineering Governance Initiative (C2G2), Governing large-scale carbon dioxide removal: are we ready? (2018); Gregory Nemet et al., Negative emissions—Part 3: Innovation and upscaling, Environ. Res. Lett. (May 2018); European Academies Science Advisory Council, Negative emission technologies: What role in meeting Paris Agreement targets? (Feb 2018) ("CCS plans in Europe have been shelved so that whatever experience is being gained globally is outside Europe. The loss in momentum in implementing CCS technologies not only has serious implications for mitigation pathways, but also one of the most commonly cited NETs [negative emissions technologies] (BECCS) assumes the availability of cost effective 'off-the shelf' CCS, while another (direct air capture) relies on the widespread availability of CO2 storage. At present, economic incentives for deploying CCS are inadequate (whether through the very low carbon price or targeted government support), while those for NET development are lacking."); Andersen & Peters, The Trouble with Negative Emissions, Science (Oct 2016). One study estimates that current rate of increase in CCS is 100 times lower than needed to meet the 2C target. See Haszeldine et al. (April 2018), Negative emissions technologies and carbon capture and storage to achieve the Paris Agreement commitments, Philosophical Transactions of the Royal Society.				
47281	63	10	63	11	Specify if this is specific for industrial technologies and sectors or drawn from a broader perspective.	accepted: text will be improved		PBL Netherlands Environmental Assessme	Netherlands
2269	64	1	64	1	in the fifth row in Table 11.5, ii should be superscript	Accepted, thanks		Hongik University	Republic of Korea
16569	64	1	64	1	in the fifth row in Table 11.5, ii should be superscript	Accepted, thanks		Korea Meteorological Administration (KM	Republic of Korea
47283	64	1	64	1	Emission reduction potential appears to be represented as both in relative and absolute terms - please harmonize to one type across the whole table to make it more easy to read (either relative, with indication of reference year, or in absolute terms)	rejected: unfortunately some of the studies do not provide the necessary data for relative and absolute terms		PBL Netherlands Environmental Assessme	Netherlands
57555	64	1	64	1	In Table 11.5, "~4.0" and "~0.6" for Sustainable Development Scenario 2020 is missing units.	accepted: will be improved		U.S. Department of State	United States of America
70473	64	1	65	1	The table header mentions "Reduction of direct CO2 emissions" while the numbers in the table seem consistent with the residual CO2 emissions.	accepted: header will be improved, actually some numbers represent the remaining absolute emissions while others show the relative reduction of emissions		European Union (EU) - DG Research &amp	Belgium
57557	64	1	65	2	The document would be stronger if this table was placed before the graphs in this section.	rejected: but will make a reference in the text before the table to help te reader to get the connection		U.S. Department of State	United States of America
57559	66	7	66	27	Add some discussion of how energy efficiency is treated in the different scenarios.	rejected: the role of energy efficiency is dicussed, unfortunately there is not sufficient space to go into more details		U.S. Department of State	United States of America
3649	66	21	66	25	Steel demand is estimated to be reduced by linger life of steel products (exteneded life of buildings) by 29% by 2070, but if this is the case, scrap availability from steel stock will be also reduced. Also, product manufacturing yields improvement must reduce processing scrap generation, thus scrap availability must be also reduced. Consequently, the needs for primary steel production from iron ore must increase, and increase CO2 emissions. Figure 11.16 on Page 11-67 is a quotation from IEA 2020a, but the report did not consider this trade-off between material efficiency and scrap availability. "JISF's Long-term vision for climate change mitigation - A challenge towards zero-carbon steel" provided the relationship between global base steel stock and scrap availability. It shows how much steel is needed to fill the growing global demand to build required steel stock to fulfil SDGs and how much scrap can be recycled at maximum from the future steel stock. (https://www.jisf.or.jp/business/ondanka/zerocarbonsteel/documents/JISFLong-termvisionforclimatechangemitigation_text.pdf)	Accepted: the relationship will be explained in the text (yes: longer life time of buildings means less scrap availability before)		JFE Steel Corp.	Japan
43977	66	21	66	23	Under the IEA Sustainable Development Scenario (SDS) 2020, combining the different material efficiency options including, to a substantial part, lifetime extension leads to 26% less cement production. This implies 26% fewer cement plants, 26% less cement employment, and downstream impacts on the entire value chain. This scenario relies heavily on the decreased use of cement, which does not reflect market demand for cement and concrete's use as a building material.	Rejected: in the text scenario assumptions are explained, reduction of cement depend is here an impact of various material efficiency improvements activities reflecting the future expectations for number of necessary buildings		Portland Cement Association	United States of America
82803	66	21	66	22	"Combining the different material efficiency options" could some of these options have overlap with circular economy strategies? Perhaps here is a good opportunity to reinforce what ME and CE and their overlap mean in the chapter, which is a distinction that became cloudy when discussing mitigation potentials in SEction 11.4.	accepted: good point, text will be aproved accordingly and relationsship (overlap) between material efficiency and circualr economy explained		Northwestern University	United States of America
57561	66	28	66	28	Footnote 23 has "several other two" clause that needs to be fixed. Also "as the study's" needs correction if referring to two or more studies.	accepted		U.S. Department of State	United States of America
48395	67	1	67	8	While the quantitative analyses are mainly derived from the IEA report, such as Figure 11.16, scenario data from AR6 scenario database should be used here, like the transport chapter.	rejected: for figure 11.16 we would have done this, but unfortunately the scenarios in the data base do not delive the leve of detail that iss necessary to discuss impact and potential role of various material efficiency strategies; figure 11.15 will be most likely deleted due to space constraints		Kyoto University	Japan
82801	67	1	67	1	consider explaining what is meant by technology performance in the figure; this is energy efficiency, no?	accepted, cf. Explaination given in comment line 840		Northwestern University	United States of America
57563	67	1	67	3	Figure 11.15 would be a lot clearer if authors reduced the number of bars in each year to two (STEPS and SDS) and put the mitigation strategies on the SDS stack. Also move the pie charts to a separate figure.	rejected: figure will most likely be removed due to space constraints		U.S. Department of State	United States of America
57565	67	1	67	4	In Figure 11.15 caption, note that "Technology performance" represents the savings from energy efficiency. See IEA ETP (2020, page 73): "Energy efficiency includes enhanced technology performance as well as shifts in end-use sectors from more energy-intensive to less energy-intensive products (including through fuel shifts). Energy-efficient technologies and services contribute to about 40% of cumulative emissions reductions to 2070 in the Sustainable Development Scenario relative to the Stated Policies Scenario."	accepted: will be added if figure remains		U.S. Department of State	United States of America
15877	67	9	67	9	In the future, Korea's manufacturing sector is also expected to improve in material effieciency. But even with the introduction of policy measures for demand management the 30~40% demand reduction mentioned in the report appears to be a very challenging target. since a solid growth is expected in final good industries and contruction sector.	rejected: looking at the numbers, the demand reduction in the scenario is less than 30-40%, however it is a kind of material efficiency offensive which is assumened here and explained in the text		KIET(KOREA INSTITUTE FOR INDUSTRIAL ECONOMICS & TRADE)	Republic of Korea
3729	67				Just a personnal interogation, but using less steel/concrete is linked to less buildings constructed. or with current meteorological events, such as storms and others, lot of constructions will have to be rebuild, so where is really the cursor on reducing material demands ?	rejected: material efficiency is not a strategy that pursues a reducing of the number of buildings, but to use less materials for the same servcde (e.g. living space)		Mines Saint-Etienne	France
70475	68	1	72	24	In this section there is much focus on the technological readiness of solutions in order to estimate their contribution towards a carbon neutral industry. This gives the impression that technology development is the limiting factor in the reduction pathways, while the role of policy is only discussed later. While certainly not all technologies are fully mature today, it has to be recognised that this is as much due to policy and pricing as it is due to the innate pace of technological development. As long as industry is not limited in the use of fossil fuels, either by direct regulation or indirectly by pricing, there is simply no incentive for a rapid rollout of low-carbon technologies, while innovation and deployment can potentially proceed very swiftly if they come with large cost benefits. This discussion would benefit from a stronger integration with the chapter on policy to give the reader a clear indication to what extent technology is actually a limiting factor for low carbon technologies and what contribution (a lack of) policy has.	accepted: the role of appropriate policies will be highlighted here in a short statement and a reference made to thepokicy section of the chapter		European Union (EU) - DG Research & Innovation	Belgium

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15873	68	2	68	2	including SDS, ETC, and LED? Or such as SDS, ETC, and LED?	accepted: text will be improved		KIET(KOREA INSTITUTE FOR INDUSTRIAL E	Republic of Korea
69883	68	23	68	34	The IEA 2020 "NZE2050" is not a full-fledge scenario, it only describes what should be acomplished by 2030 to allow reaching NZE by 2050. For example, the share of low carbon hydrogen in ammonia and methanol production goes to 15% by 2030 in the NZE2050	accepted: text will be improved		Institut Français des Relations Internationales	France
69885	68	33	68	34	The exact wording is slightly different: 25% of total heat used in the sector is provided by electricity or low-carbon fuels (i.e. electrification not necessarily only by heat pumps, low-carbon fuels may include biofuels, etc.)	accepted: text will be improved		Institut Français des Relations Internationales	France
47285	68	35	68	39	As a result I would therefore be more in favour of synthesizing the whole section in a similar way as colleagues have done for the "IEA depictions of PV diffusion over time" (an annually returning analysis across multiple platforms to prove the underestimation of IEA's innovation assumptions) - to see how the thinking of IEA changes over time. What shifts in thinking have developed over time, as promised in the introduction by announcing an analytical backcasting approach)? Current written pieces are just asking too much mental capacity to deduct this myself.	rejected: the table in the section has exactly that role and shows development over time, but certainly associated with different assumptions for the undderlying GHG mitigation goal		PBL Netherlands Environmental Assessme	Netherlands
3653	69	5	69	7	"The key conclusion of the scenario analysis is that significant cuts in GHG emissions and even close to net zero emission from the largest sources such as steel could be achieved by 2050 by deploying already well known option" is not true. There is no commercial zero carbon steel plant exist in the world, and though various pilot plants for hydrogen reduction iron process are planned, the commercial scale success of such process is yet to be seen.	rejected: it is not stated, that all relevant technologies are already mature, but is said that all options are principially "known"		JFE Steel Corp.	Japan
57567	69	7	69	9	While this may be the case, do not under emphasize the value that continued and sustained energy efficiency must play to enable these transformational strategies to succeed.	rejected: the term "by deploying already well known options" includes energy efficiency		U.S. Department of State	United States of America
15875	69	16	69	16	a preposition in front of substantial might be needed	Accepted: text will be adapted		KIET(KOREA INSTITUTE FOR INDUSTRIAL E	Republic of Korea
47287	69	23	69	31	Current text feels like the Xth repetition of the strategies that can be implemented in the industry sector- it would be more easier to remember if take-aways from studies can be grouped together.	Accepted: text will be adapted		PBL Netherlands Environmental Assessme	Netherlands
47289	69	32	69	35	Cite the "sector specific scenarios" addressed in this paragraph.	Accepted: text will be adapted		PBL Netherlands Environmental Assessme	Netherlands
57569	69	38	69	40	Energy efficiency must pair with new technology. The authors should consider deleting "have only limited unexhausted potential." It is confusing as written.	Accepted: text will be adapted		U.S. Department of State	United States of America
47291	70	1	70	4	Unclear sentence - I do not understand if the sentence says if the age profile matters or not? Or if its willingness?	Accepted: text will be adapted		PBL Netherlands Environmental Assessme	Netherlands
2271	71	1	71	3	The range of contribution to emission reduction is so wide, Hence It is difficult to prioritize reduction measures.	rejected: do not understand the comment as now strategies are shown in the figure		Hongik University	Republic of Korea
16571	71	1	71	3	The range of contribution to emission reduction is so wide, Hence It is difficult to prioritize reduction measures.	rejected: do not understand the comment as now strategies are shown in the figure		Korea Meteorological Administration (KMA)	Republic of Korea
47293	71	5	71	19	Current text feels like a listing of published results but does not synthesize. Why is this information and these individual scenarios interesting to look at? Do they have commonalities? Its clear by now that the scenarios vary in layout, configuration etc, but what is the robust message that we can draw from it?	accepted: good point, most likely lines 10 to 19 could be deleted without loosing to much information or substanially shorted, however it should be said that Zhou et al is one of the very few studies that rfelcts material efficiency for China		PBL Netherlands Environmental Assessme	Netherlands
82805	71	5	72	8	consider merging this content, which unpacks some of the results from additional scenario studies, with the content in Section 11.4.2.2 to: (a) reduce length; and (b) combine more scenarios into the synthesis of findings, differences, and commonalities	accepted: text will be improved		Northwestern University	United States of America
72867	71	8	71	8	Cannot understand the part of the sentence "respectively demand management"	accepted: text will be improved		EE-Consultant	France
3655	71	9	71	19	Shorting of scrap and build period of primary steelmaking process from typical 40 years to 25 years is necessary to accelerate CO2 emission reduction. On Figure 11.18, by such early retirement of existing steel plants will make net zero emission of steel by 2050. However, as stated on Page 11-75 Line39, average age of blast furnace in China, which produces more than half of the crude steel today, is 10-12 years old. Therefore, 25 years retirement of the existing process means China must shut down more than half of the existing blast furnace within the next 13-15 years. Since most of them are invested to recover original capital investment during the 40 years expected operational life (which is significantly shorter than Japanese case), such early retirement will cause an unbearable financial burden to Chinese steel companies. Therefore, though on paper, accelerating zero emission steel by early retirement is possible, but it is unlikely to happen in real world.	rejected: it is quite clear that without appropiate policies and support for effected companies such drastic change (early substitution of industrial processes) will not happen, following the if-wenn <architecture of scenarios such policy support is grounded in th scenario assumptions		JFE Steel Corp.	Japan
63105	71	9	71	19	According to these sentences, a citation describes the mitigation scenarios that can exceed China's official targets for 2030 and 2050. However, it does not mention the difficulties and whether the scenario is feasible. It is suggested to revise these sentences.	rejected: it is quite clear that without appropiate policies and support for effected companies such drastic change (early substitution of industrial processes) will not happen, following the if-wenn <architecture of scenarios such policy support is grounded in th scenario assumptions		National Climate Center, China Meteorological Administration	China
3731	71	11			For 2050, … (add coma)	accepted: will be improved		Mines Saint-Etienne	France
3733	71	13			For achieving that goal, … (add coma)	accepted: will be improved		Mines Saint-Etienne	France
3735	71	13			As expected, … (add coma)	accepted: will be improved		Mines Saint-Etienne	France
29803	71	20	71	26	Please consider rephrasing. CCS is included in all scenarios in Material Economics, 2019, so this para seems to be misquoting its source.	rejected: In the described scenarios CCS was not taken into consideration as a mitigation option by the authors of the scenarios		Norwegian Environment Agency	Norway
57571	72	2	72	3	Concerning Table 11.6, "end of life plastic" entry, would it make more sense to eliminate this entry and add its contribution to the Circularity entry?	rejeted: given the relevant role of end of life plastics (i.e. further use of the materrials) for the specific scenarios it make sense to seperate it from the broader term circularity		U.S. Department of State	United States of America
3657	72	5	72	8	Table 11.6 shows that deep decarbonization of steel industry requires 25~65% annual investment increase and 2-20% production cost increase. First, the increase of cost is stated as 10~50% in Page 11-43 and 20-40% on P11-5 in Executive Summary. Those are significantly big difference. Second, since steel business is relatively low margin business, and profit margin over revenue is around 10~20%, it might be almost impossible for the industry to self-finance 25~65% more investment for long period from its free cash flow. Furthermore, the cash flow will be significantly shrunk by 2-20% cost increase (or more), and by bearing early retirement cost of existing process, which are in pre-mature depreciation process. In summary, significant amount of public funding and subsidy shall be necessary to decarbonize steel industry in the next decades, but such quantitative financial analysis has not yet be done by anyone.	accepted: number will be checked (cross reference to toher sections of the chapter), yes substantial cost increase for climate friendly steel prroduction requires policy support (financial support) or the development of a global green steel market including willingness of customer to cover additional costs (reference to policy section needed).		JFE Steel Corp.	Japan
82807	72	9	72	24	there is some conceptual overlap between this paragraph and the earlier cost data discussion in section 11.4.1.5; consider merging and consolidating	accepted: text will be improved		Northwestern University	United States of America
3737	72	11			According TO …	accepted: text will be improved		Mines Saint-Etienne	France
10809	72	45	72	47	verb seems to be missing	accepted: text will be improved		CNRS	France
82811	73	2	73	2	perhaps add a sentence stating that this section considers four cross-sectoral opportunities more clearly: (1) using waste heat from other sectors; (2) using waste materials from other sectors; (3) substituting materials from one sector (wood) for another; and (4) using industrial plants for demand response and load balancing for the grid. However, it strikes me that you might move the earlier discussion of eco-industrial parks and put that here.	Not accepted.		Northwestern University	United States of America
47295	73	7	73	47	It seems more useful to define cross-sectoral interaction first (how is this different from circular economy, or just the creation of new value chains?) and then introduce the considered concepts, like district heating, clinker substitution, etc.? The innovativeness of these examples can also be better elaborated.	Thank you. revised		PBL Netherlands Environmental Assessment Agency	Netherlands
57573	73	12		36	These two paragraphs are redundant with previous material.	Thank you. The whole chapter wil be edited for clarity, language and avoid repetition		U.S. Department of State	United States of America
47299	73	20	73	23	How is this different from the current practice? Many (heavy) industries have already clustered organically and share infrastructure, with future innovations being expected to be planned in close vicinity of its users.(see also p76 L19+ of this chapter)	Agree, it is not that different.		PBL Netherlands Environmental Assessme	Netherlands
43979	73	24	73	26	IPCC asserts that there is the potential for up to 95% substitution with blast furnace slag in limited applications and up to 45% with other substitute applications. Slag and fly ash supplies for clinker substitution are waning and under tremendous market pressure. IPCC cannot assume the continued market availability of slag and fly ash at those quantities needed for increased clinker substitution in the future.	Thank, we will make clear diminishing availability of slag		Portland Cement Association	United States of America
82809	73	24	73	28	consider stressing that blast furnace slag comes from the steel industry here, so that it's clear why clinker substitution is being discussed here as a "cross sectoral strategy" instead of in the cement section, but you should also probably point out that steel slag will diminish due to moves away from blast furnaces that you suggest earlier	Thanks, we will make this clear		Northwestern University	United States of America
3537	73	28	73	28	After "…Jokar and Mokhtar 2018)." could you please 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, ground granulated blast-Furnace Slag Portland cements carbonate more than other types of Portland cements (Andrade and Sanjuán 2018). Furthermore, this is a significant lever considered in the Roadmap 2050 of the Spanish Cement Industry to achieve zero net-carbon emissions by 2050 (Sanjuán et al. 2020)." 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 Sanjuán, M.A.; Argiz, C.; Mora, P.; Zaragoza, A. Carbon Dioxide Uptake in the Roadmap 2050 of the Spanish Cement Industry. Energies 2020, 13, 3452. https://doi.org/10.3390/en13133452	Word count prevents elaborating such detail		IECA	Spain
10429	73	28	73	28	After "…Jokar and Mokhtar 2018)." could you please 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, ground granulated blast-Furnace Slag Portland cements carbonate more than other types of Portland cements (Andrade and Sanjuán 2018). Furthermore, this is a significant lever considered in the Roadmap 2050 of the Spanish Cement Industry to achieve zero net-carbon emissions by 2050 (Sanjuán et al. 2020)." 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 Sanjuán, M.A.; Argiz, C.; Mora, P.; Zaragoza, A. Carbon Dioxide Uptake in the Roadmap 2050 of the Spanish Cement Industry. Energies 2020, 13, 3452. https://doi.org/10.3390/en13133452	Word count prevents elaborating such detail		Oficemen	Spain
11585	73	28	73	28	After "…Jokar and Mokhtar 2018)." could you please 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, ground granulated blast-Furnace Slag Portland cements carbonate more than other types of Portland cements (Andrade and Sanjuán 2018). Furthermore, this is a significant lever considered in the Roadmap 2050 of the Spanish Cement Industry to achieve zero net-carbon emissions by 2050 (Sanjuán et al. 2020)." 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 Sanjuán, M.A.; Argiz, C.; Mora, P.; Zaragoza, A. Carbon Dioxide Uptake in the Roadmap 2050 of the Spanish Cement Industry. Energies 2020, 13, 3452. https://doi.org/10.3390/en13133452	Word count prevents elaborating such detail		UNIVERSITY	Spain
43495	73	28	73	28	After 2018 Add "Mokhtar,A,Nasooti,M,A decision support tool for cement industry to select energy efficiency measures,Energy Strategy Reviews,https://doi.org/10.1016/j.esr.2020.100458)	Not for this section.		Head of national center for forecasting and weather hazards management of Islamic Republic of Iran Meteorological Organization (IRIMO)	Iran
50401	73	28	73	28	After 2018 Add "Mokhtar,A,Nasooti,M,A decision support tool for cement industry to select energy efficiency measures,Energy Strategy Reviews,https://doi.org/10.1016/j.esr.2020.100458)	Same as above.		Islamic Republic of Iran Meteorological Organization (IRIMO)	Iran
43981	73	30	73	38	IPCC does not recognize the significant environmental footprint of cross-laminated timber. Removing trees from forests for building materials removes a carbon sink.	Not accepted.		Portland Cement Association	United States of America

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
77797	73	31	73	38	New wood replacement building material products, in particular production of sustainable MDF (medium density fibreboard) from waste agricultural materials, rice straw in particular as is being demonstrated at industrial scale in new facilities in California (https://www.eurekamdf.com/) could lead to significantly reduced GHG emissions also from the avoidance of methane emissions from baseline underwater, anaerobic decomposition of rice straw prior to rice farmers planting the next cultivation cycle.	Needs literature.		Climate Wedge LLC	United States of America
77145	73	33	73	34	Cross-laminated timber buildings have limited possibilities, but will always be a serious fire risk. Concrete buildings have no fire risk, are extremely durable under seismic and other adverse conditions, as well as providing embedded heat storage in the concrete.	Not to be disccused here. it will depends on the regulation and building technology.		Expert Reviewer AR6 SOD WG1	Ireland
10425	73	34	73	34	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	Not to be disccused here. it will depends on the regulation and building technology.		Oficemen	Spain
11581	73	34	73	34	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	Same as above.		UNIVERSITY	Spain
47297	73	34	73	35	Expected reading about examples of how construction periods have shortened, but only mentions examples of buildings now.	Revised. But it should be in the building section.		PBL Netherlands Environmental Assessme	Netherlands
3535	73	36	73	36	It would neccesary to add a reference. Currently, high-rise buildings (with more than ten floors) are made with steel or reinforced concrete.	Not accepted.		IECA	Spain
10427	73	36	73	36	It would neccesary to add a reference. Currently, high-rise buildings (with more than ten floors) are made with steel or reinforced concrete.	Same as above.		Oficemen	Spain
11583	73	36	73	36	It would neccesary to add a reference. Currently, high-rise buildings (with more than ten floors) are made with steel or reinforced concrete.	Same as above.		UNIVERSITY	Spain
82813	73	42	73	45	for demand response consider reviewing and citing this LBNL report: https://eta.lbl.gov/publications/2025-california-demand-response	Not about industry.		Northwestern University	United States of America
3739	73	46		47	could from locations -> rephrase	Revised		Mines Saint-Etienne	France
57575	74	4	74	14	Make more of a connection to industry in this discussion. Are the companies referenced all manufacturing companies?	Not accepted.		U.S. Department of State	United States of America
57577	74	4			This paragraph on "Environmental pressure" is a good start but could benefit from elaboration and expansion, as follows: (1) more than 1,200 companies and financial institutions have set value-chain emissions reduction targets designed to systemically accelerate industrial mitigation; (2) policymakers are introducing mandatory emissions and risk disclosure in concert with other stakeholders; and (3) financial institutions are poised to accelerate industrial mitigation with their portfolio net-zero targets, but additional data and institutional development is needed.	(1) is in next section, (2) is beyond this section (should be in policy) (3) is important but not here.		U.S. Department of State	United States of America
70477	74	4	74	4	Please considerreplacing "Environmental pressure" by "societal pressure", as "environmental pressure" is coined by the OECD as the pressure human activities exerts on the environment and that is not being meant here	Revised		European Union (EU) - DG Research &amp	Belgium
57579	74	9	74	10	Consider the following edits: "This requires harmonised and widely accepted methods for environmental and corporate carbon footprint and project carbon accounting (i.e., GHG Protocol)."	Beyond this section.		U.S. Department of State	United States of America
39059	74	11		13	Need a close parentheses in line 13.	Thanks.		Green Planet Consulting Ltd.	United Kingdom (of Great Britain and Northern Ireland)
57581	74	16	74	25	If this section is about supply chains, there should be more literature to include.	Not accepted. This section is not about supply chain.		U.S. Department of State	United States of America
57583	74	16			There has been a lot of effort undertaken by the private sector already, such as Walmart and Apple on their supply chain sustainability.	Yes, but no literature provided		U.S. Department of State	United States of America
82815	74	16	74	16	there are a few issues with this section: (1) "net" GHG impact implies much more than an attributional carbon footprint of an industrial product which is what one would get by estimating each part/machine/production, it would require a consequential LCA approach; (2) even attributional LCA is super complex and faces lots of barriers (data gaps, system boundary differences, etc.) but the first sentence implies it is easy and doable broadly (it is not); (3) the purpose of this section is not clear; if it is meant to promote the benefits of net GHG impact analysis it should be far more comprehensive and nuanced than it is now (there are whole fields on this topic, e.g., LCA and Industrial Ecology), cite some relevant efforts like the Carbon Leadership Forum, discuss some of the challenges of making such analyses more mainstream, and why they are needed for the industrial decarbonization agenda (e.g., to support green procurement standards, low-carbon product labels, etc.). So, a substantial expansion would be needed to make this section more useful to readers.	Agreed but already in it.		Northwestern University	United States of America
57585	74	40	76	40	Clarify if the paragraph on page 76, lines 1-14, refers to China or global industry.	Only the age of curent plants, 10-12 years, applies to China. We have clarified this in the text.		U.S. Department of State	United States of America
70479	74	40	76	40	This paragraph could be shortened and it could be merged with the discussion in 11.4.2.2 on the survival rates. What I miss here is a link with the discussion on "stranded assets" (as treated in Chapter 15) as most of the investments in those carbon intensive sectors can be regarded as stranded.....	Reject: the detail on 'carbon lock-in' or 'committed emissions' , and the methodlgoly for calcuating 'lock-in" is included in more detail, because this is cutting endge research which has emerged since AR5. The issues of lick-in could prove to be challenging to overcome, and challenge efforts to decarobinse industry. We focus in this chapter on outling the issue for industrial facillities, xpected lifetimes, and their impact on decarbonisation, whereas Chpt15 examines the investment required to overcome this problem, across all sectors.		European Union (EU) - DG Research & Innovation	Belgium
15283	75	19	75	28	This section, SPM and CH2 (see Section 2.7) mention a new concept "committed emission" a lot. It is suggested to add an explanation of this term in Annex A (Glossary).	We've clarified the text in this section: "'carbon lock-in' or 'committed emissions' (where existing industrial facilities continue to emit emissions well into the future)" in the text.		China Meteorological Administration	China
15285	75	31	75	35	This formulation uses the information and conclusions from the reference of Tong et al. 2019. It is noted that some of the original data in this paper are non-public data which lacks transparency and should be quoted with caution. It is suggested to delete this reference as well as "Tong et al. (2019) use unpublished unit-level data from China's Ministry of Ecology and Environment to obtain a more robust estimate of the age profile of existing capacity in the cement and iron and steel sectors in the country."	Reject. Tong e tal. is a peer-reviewed jounral paper and therefore is considered a credible publication. The text "uses unpublished data" was added to qualify the data source, in response to a similar comment in a prior revision round.		China Meteorological Administration	China
47301	75	41	75	43	Sentence requires further clarification on the assumed scenario for these carbon budgets - is it BAU, or a pathway towards a climate target or net-zero industrial emissions?	The estimate of 196 GtCO2 is not from one of the IEA scearnios (Stated Policy or Austainable Developmet) but instead reflects the current state of play, of industrial facillities in operation today. We have updated the text for clarity: "However, the studies come to differing estimates of cumulative emissions by 2050 from existing industry infrastructure, in the absence of early retirement or other emissions reduction measures: 196 GtCO2 in the IEA (2020a) study, and 162 GtCO2 in the Tong et al. (2019) study."		PBL Netherlands Environmental Assessme	Netherlands
57587	76	1		40	The section doesn't offer a lot of new information. The part on lifetime of physical assets is also addressed in earlier sections.	Reject. See comment 70479.		U.S. Department of State	United States of America
57589	76	14			Consider a statement regarding or emphasis placed on the importance of early action, which will reduce the need for more aggressive actions to meet longer-term targets.	Reject: this point is mentioned in other places throughout the chapter.		U.S. Department of State	United States of America
84939	76	15	76	24	It's worth making the poin that industrial facilities have varied lifetimes and they are typically not on regulated depreciation timetables like power plants. The lifetime is "as long as it's profitable"	Reject. This is covered adequately by the text "The cost of retrofitting or retiring a plant before the end of its lifetime depends on plant specific conditions as well as a range of economic, technology and policy developments"		ClimateWorks Foundation	United States of America
3741	76	23			remove the before complexity	Corrected		Mines Saint-Etienne	France
14833	77	19	77	21	This recent study could be mentioned : DOI:https://doi.org/10.1016/j.joule.2021.02.018, Low-carbon production of iron and steel: Technology options, economic assessment, and policy - Zhiyuan Fan, S. Julio Friedmann	Check policy content and relevance		Indépendant consultant	France
47303	77	28	77	28	Technically true statement, but advised to be mindful of the used semantics and difference between the used framing of "zero emissions for industry" over the possibly intended "net-zero economy" ambitions that are embedded in various national policies and climate laws.. These are not (always) mutually interchangeable.	Thank you for noting this. We will be clear about our perspective.		PBL Netherlands Environmental Assessme	Netherlands
70481	77	31	77	39	I would say that industry has "so far largely" been sheltered from carbon pricing. In the EU ETS, after a decade of overallocation, industry is nowadays facing increasing shortage of available allowances for compliance as the share of freely allocated allowances is no longer enough to make up for verified emissions	Will add "so far"		European Union (EU) - DG Research & Innovation	Belgium
57591	77	41	77	4	Tell readers where to find the list of SDGs in the report.	TOC outlines this. Also, "Line of Sight" of the SDGs related to Chapter 11 is listed the SDG linked tables in Chapter 17		U.S. Department of State	United States of America
31753	78	0			For Electrification & fuel switching, table 17.7 in chapter 17 shows co-benefits with many more SDGs. Check for consistency	Figure 11.19 has been updated to align with the text		Ahmedabad University	India
31755	78	0			For CCU & CCS, table 17.7 in chapter 17 shows co-benefits with many more SDGs. Check for consistency	Cross reference made to Table 17.7		Ahmedabad University	India

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
31757	78	0	80		P80L23 says "With energy being such an important cross-cutting issue to sustainable development, some SDGs, such as SDG 1, 3, 4, 5 (UNDP 2018) are co-beneficiaries to using electrification and fuel switching as a climate action mitigation option". However in Figure 11.19 these SDG icons are not shown.	Figure 11.19 has been updated to align with the text		Ahmedabad University	India
20089	78	3	78	4	For a risk assessment excercise based on stakeholder engagement to assist decision making in the iron and steel sector of Austria see: -Labella, Á., Koasidis, K., Nikas, A., Arsenopoulos, A., & Doukas, H. (2020). APOLLO: A Fuzzy Multi-criteria Group Decision-Making Tool in Support of Climate Policy. International Journal of Computational Intelligence Systems, 13(1), 1539-1553.	Reference added		National Technical University of Athens, Greece	Greece
20157	78	4	78	4	Also: Labella, Á., Koasidis, K., Nikas, A., Arsenopoulos, A., & Doukas, H. (2020). APOLLO: A Fuzzy Multi-criteria Group Decision-Making Tool in Support of Climate Policy. International Journal of Computational Intelligence Systems, 13(1), 1539-1553.	Relevant reference already added		National Technical University of Athens	Greece
3743	78	12		13	sentence unclear to me	The sentence has been updated to enhance clarity.		Mines Saint-Etienne	France
57593	78	14	78	17	The information in Figure 11.19 would be better presented as a table -- each strategy on the left (e.g., Electrification and Fuel Switching) in the left column, and the numbered boxes on the right (increased in size to be legible).	Information in a table/figure format has been discussed. Choice made was to use a figure		U.S. Department of State	United States of America
63251	78	15	78	15	Figure 11.19: Include SDG 14 in terms of marine pollution (i.e construction material/industrial waste/run-off)	Suggestion has been considered but not considered because of insufficient reference support.		Environment and Climate Change Canada	Canada
57595	78	15	78	17	The linkages between energy efficiency and the SGDs are under-represented in Figure 11.19. Since many energy efficiency measures reduce the use of fossil fuels per ton of product produced, SDG3 should apply (e.g., reduced ambient air pollution). Since almost all energy efficiency measures pay back then are net positive in terms of costs after ~5 years, SDG 7 should apply. Since many energy efficiency measures are applicable for production of infrastructure materials (e.g., cement/concrete as building materials), SDG11 should apply. Since most energy efficiency measures for industry apply to production of material commodities, SDG12 should apply. Additional SDGs could be added to the electrification and fuel switching option, given that these are typically understood to mean a reduction in the use of fossil fuels (with the assumption that the power grid is decarbonizing).	Sub-section has been updated with recommendations. Relevant citations have also been added.		U.S. Department of State	United States of America
57597	78	15	78	17	Figure 11.19 needs to align with Figure SPM.11. In Figure SPM.11, SDGs 7, 8, 9, and 13 are indicated as having synergies with industry energy efficiency, whereas Figure 11.9 here has only 8, 9, and 13. Further, there needs to be better alignment between sectors shown in Figure SPM.11. For example, the energy efficiency measures for buildings (envelope improvement, HVAC, efficiency appliances) show synergies with many more SDGs than are shown for industry. Same with transport fuel efficiency. These three end-use sectors should be aligned in terms of how their energy efficiency measures and the SDGs align.	SDG co-benefits from Energy Efficiency have been updated folowing his review		U.S. Department of State	United States of America
14823	78	17	78	17	Figure 11.19 : SDG7 should be added for energy efficiency, consistently with page 80 line 8.	Figure 11.19 updated accordingly.		Indépendant consultant	France
82817	78	17	78	17	the icons in the figure are difficult to read; consider enlarging or converting the image to a table-type graphic?	Figures would be professionally designed at the end.		Northwestern University	United States of America
31759	78		80		P80L41: "Indeed, SDGs 7 to 11 have considerable significance for the sustainable implementation of CCU technologies." However in Figure 11.19 all the SDG icons are not shown.	Sentence have now being deleted.		Ahmedabad University	India
57599	79	1	79	25	Section 11.5.3.1 is well-written, well-referenced, and informative. Would a discussion of sufficiency or the saturation effect also fit here (lines 16-20)? For example, in modeling of Chinese demand, there is a point where households do not need additional products -- i.e., a saturation of products such as clothes washers/dryers, refrigerators, etc.	Whiles relevant, specific this discussion of this would bot be added as it still falls under the broad context of product demand reduction		U.S. Department of State	United States of America
31725	79	4	79	5	"For instance, materials efficiency provides opportunities to reduce the pressures and impacts on environmental systems (SDG 6)"- I think this will be SDG 8 instead of 6. Please see target 8.4 and the two indicators under it https://unstats.un.org/sdgs/indicators/Global%20Indicator%20Framework%20after%202020%20review_Eng.pdf	SDG 8 has been added as another potential co-benefit. Citation souce also provided.		Ahmedabad University	India
3745	79	16			While -> remove s ?	Edit has been impleented and sentence updated for better clarity.		Mines Saint-Etienne	France
31727	79	20	79	21	"As co-benefits, the reduction in consumption and demand for products and services also generates a reduction in post-consumption waste (SDG 6)"- SDG 6 specifies wastewater only. Here according to the context SDG 12 fits better (targets 12.3, 12.4, 12.5)	SDG 12 has been added as another potential co-benefit. Citation souce also provided.		Ahmedabad University	India
70483	79	22	79	23	This claim is not true from an economic perspective. As the national income is made up by consumption and investments, a reduction in consumption directly reduces economic growth, not necessarily through a reduction in the sales tax!!	Sentence updated for better clarity		European Union (EU) - DG Research & Innovation	Belgium
57601	79	27	80	3	Section 11.5.3.2 is well-written, well-referenced, and informative. Are there more recent Geng publications to cite? Geng et al. (2012, 2013) are a bit old for AR6. Geng Yong is a prolific researcher with many publications, so it would be great to include something more recent.	Agree references are old but also the most appropriate in this context		U.S. Department of State	United States of America
80393	79	27	80	3	Here it must be pointed out that in terms of circular economy and industrial wastes there are several types of industrial wastes that are transformed to alternative fuels for industrial processes, and thus their added value is high and supports the circularity in industrial sector. A good example are the multiple alternative fuels of cement industry derived from multiple waste sources (see publication e.g : Chatziaras, N., et al. (2016), "Use of waste derived fuels in cement industry: a review", Management of Environmental Quality, Vol. 27 No. 2, pp. 178-193. https://doi.org/10.1108/MEQ-01-2015-0012)cand others like https://doi.org/10.1016/j.conbuildmat.2017.07.102, https://doi.org/10.1016/j.rser.2017.10.065 This point is of paramount importance to achieve circularity in industrial wastes and it goes beyond the scrap approach, and thus should be included here in this point.	Recommendation was deemed relevant and so included in the review.		University of West Attica, Department of Electrical and Electronics Engineering	Greece
3747	80	1			remove such	Done.		Mines Saint-Etienne	France
57603	80	5	80	5	Improving energy efficiency would also improve air quality (as one of the key co-benefits). Would clean air fit/be covered under one of the SDGs?	Text and Figure 11.19 has been updated with relevant referenc cited.		U.S. Department of State	United States of America
57605	80	5	80	15	The linkages between energy efficiency and the SGDs are under-represented. Since many energy efficiency measures reduce the use of fossil fuels per ton of product produced, SDG3 should apply (e.g., reduced air pollution). Since almost all energy efficiency measures pay back then are net positive in terms of costs after ~5 years, SDG7 should apply. Since many energy efficiency measures are applicable for production of infrastructure materials (e.g., cement/concrete as building materials), SDG11 should apply. Since most energy efficiency measures for industry apply to production of material commodities, SDG12 should apply. Would it be possible to add some additional discussion and references for these linkages?	Thank you this has been revised		U.S. Department of State	United States of America
57607	80	6		10	There is a lot of literature that demonstrates the energy efficiency co-benefit on air quality thus health. Suggest to add that angle. See, for example: Ali Hasanbeigi, Agnes B Lobscheid, Yue Dai, Hongyou Lu, Lynn K Price. 2012. Quantifying the Co-benefits of Energy-Efficiency Programs: A Case Study of the Cement Industry in Shandong Province, China. Christopher J Williams, Ali Hasanbeigi, Lynn K Price, Grace Wu, 2012. International Experience with Quantifying the Co-Benefits of Energy Efficiency and Greenhouse Gas Mitigation Programs and Policies	SDG co-benefits from Energy Efficiency have been updated folowing his review		U.S. Department of State	United States of America
63107	80	6	80	15	In China, the industrial structure adjustment path led by energy-saving policy can maximize the collaborative realization of other SDG: promote the development of high value-added industries, enhance the employment of high value-added industries, promote carbon emission reduction and water resources conservation, and improve the fairness of regional development. It is suggested that this case be added to the text to support the arguments--- "a vast majority of the extant literature points out that energy efficiency improvements can deliver superior employment opportunities (SDG 8) in a green economy"and"Energy efficiency has also been reported to deliver positive changes in productivity (SDG 8) through industrial innovation (SDG 9). Reference: Wang J et al. How to balance China's sustainable development goals through industrial restructuring: A multi-regional input–output optimization of the employment–energy–water–emissions nexus. Environmental Research Letters 2020, 15, 034018. https://iopscience.iop.org/article/10.1088/1748-9326/ab666a	Thank you. Revised		National Climate Center, China Meteorological Administration	China
57609	80	17	80	24	Some additional SDGs could be added to the electrification and fuel switching option, given that these are typically understood to mean a reduction in the use of fossil fuels (with the assumption that the power grid is decarbonizing).	Text and Figure 11.19 has been updated with relevant referenc cited.		U.S. Department of State	United States of America
80395	80	17	80	24	Here it must be pointed out that in terms of circular economy and industrial wastes there are several types of industrial wastes that are transformed to alternative fuels for industrial processes, and thus their added value is high and supports the circularity in industrial sector. A good example are the multiple alternative fuels of cement industry derived from multiple waste sources (see publication e.g : Chatziaras, N., et al. (2016), "Use of waste derived fuels in cement industry: a review", Management of Environmental Quality, Vol. 27 No. 2, pp. 178-193. https://doi.org/10.1108/MEQ-01-2015-0012)cand others like https://doi.org/10.1016/j.conbuildmat.2017.07.102, https://doi.org/10.1016/j.rser.2017.10.065 This point is of paramount importance to achieve circularity in industrial wastes and it goes beyond the scrap approach, and thus should be included here in this point.	Additional relevant co-benefits of SDGs from Energy Eficiency have been added following the review.		University of West Attica, Department of Electrical and Electronics Engineering	Greece
5531	80	20	80	20	replace Renewables" by "low carbon sources"	Done.		Retraité/ Pdt d'association	France
31729	80	33	80	35	"Such co benefits for CCS include control of non-CO2 pollutants (SDG 3), direct foreign investment and know how (SDG 9)"- Instead of SDG 9 here SDG 17 (indicator 17.3.1) fits better. Also see 7.b.1 and 10.b.1	Thanks revised		Ahmedabad University	India
7705	81	7			In providing strategies and policies on preventing increasing of greenhouse gases, besides of global attitude, regional attitude and role of local governments and local conflicts must be attention.	If local conflicts refers to the the difficult social acceptance of price increases due to carbon prices or the need to include a just transition pathways, then we provide references		Meteorological	Iran
9025	81	7	81	7	in providing strategies and policies on preventing increasing of greenhouse gases, besides of global attitude, regional attitude and role of local governments and local conflicts must be attention.	If local conflicts refers to the the difficult social acceptance of price increases due to carbon prices or the need to include a just transition pathways, then we provide references		IRIMO	Iran
2391	81	7	81	28	This paragraph is describing incremental changes, not a wholesale transformation of one of the world's largest GHG sectors. It lacks historical perspective of realistic energy system transitions. We are talking about huge scale, very heavy equipment, huge output of materials, factories, supply chains, not lightweight cell phones; very long lived assets, very low margin, slow to change industries like iron and steel, glass, and cement; and a litany of difficult to surmount policy, technology, cost, and institutional barriers. See the work of Gross, Energy Policy 123 (2018) 682–699 ; A. Grubler, among others for example. I disagree with the tone and tenor of this paragraph as being misleading and unrealistic. Instead of sounding the necessary alarm and emphasizing the scope of this herculean challenge, this text seems highly reassuring and soothing.	Agreed. Language changed to emphasize the urgency and the herculean effort needed		Lawrence Berkeley Lab	United States of America
2389	81	7	81	8	"Industrial decarbonisation is possible on the mid-century horizon": This is NOT supported by historical data, current trends, current policies, or current technology status. If this super optimistic language is used then it must be coupled with super strong clarification of how this would be possible: massive scale up of development and deployment, massive scale up in industrial/government/academia partnership and coordination, industrial policies at a scale not seen in 80 years, essentially war-time like mobilization for a couple of decades. The policies that are needed go far beyond what line 8 mentions.	Agreed. Language changed to emphasize the urgency and the herculean effort needed		Lawrence Berkeley Lab	United States of America
85105	81	7	81	8	There is a missing word in the phrase "regionally and sectorally specific term policy strategies" - presumably "long term" is meant.	Agreed. Revised		Australian Industry Group	Australia
20091	81	9	81	15	Similar arguments for the industrial low carbon transitions are discussed in Koasidis et al. (2020): -Koasidis, K., Nikas, A., Neofytou, H., Karamaneas, A., Gambhir, A., Wachsmuth, J., & Doukas, H. (2020). The UK and German low-carbon industry transitions from a sectoral innovation and system failures perspective. Energies, 13(19), 4994.	Agreed. Added.		National Technical University of Athens, Greece	Greece
52567	81	9	81	9	Use "Transitions" instead of "Transformations"	Agreed. Revised		Sustainability Advisor to the Minister Ministry of Petroleum and Mineral	Saudi Arabia
20159	81	15	81	15	Also: Koasidis, K., Nikas, A., Neofytou, H., Karamaneas, A., Gambhir, A., Wachsmuth, J., & Doukas, H. (2020). The UK and German low-carbon industry transitions from a sectoral innovation and system failures perspective. Energies, 13(19), 4994.	Already cited		National Technical University of Athens	Greece
85107	81	23	81	23	Reference to "policies need to be innovative and definitive about zero emissions" presumably should reference "net zero", as it is acknowledged that some activites are likely to have residual emissions while others could reach neutrality, absolute zero or negative emissions.	Agreed. Revised		Australian Industry Group	Australia
57611	81	30	81	32	This statement (even if labeling, disclosure, and procurement added to the list) is a bit broad and dismissive. While energy efficiency is well-established in many countries, it is not well-established globally. This statement is a bit Western-centric (although China also has decades of energy efficiency experience). Perhaps modify to say something like: "In many countries, energy efficiency is a well-established policy field with decades of experience from voluntary and negotiated agreements, regulations, standards, labels, energy audits, disclosure, procurement, and DSM programs (see AR5), but there are also countries and regions where the application of energy-efficiency policy is absent or nascent."	Agreed. Revised		U.S. Department of State	United States of America
57613	81	35	82	7	These are well-written and informative paragraphs, but weak on references. Add citations.	Agreed. Revised		U.S. Department of State	United States of America

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
82819	81	35	81	42	unless I missed it, I could not find a crisp definition of materials demand management and its relationship to ME or CE. Perhaps good to make the distinction between demand management, ME, and CE clearer much earlier? (see previous comments to this effect)	This will be addressed in 11.3		Northwestern University	United States of America
14825	82	4	82	6	The exemple of the US 45Q tax credit could be mentioned, consistently with chapter 6 page 40 line 8.	Agreed. Revised		Indépendant consultant	France
2393	82	9	81	11	"The potential of global governance to contribute to the decarbonisation of energy intensive industry through intergovernmental and transnational institutions has remained very much underexploited (Oberthür et al. 2020)." : this language again is extremely polite and understated. Make it much more explicit and active, again reflecting the gravity of the situation: e.g. "Unless there is much greater global governance to contribute to the decarbonisation of energy intensive industry through intergovernmental and transnational institutions, it is questionable that the world will achieve industry decarbonization by 2050 given the fact that most all of the key markets are global marketplaces."	Agreed. Revised		Lawrence Berkeley Lab	United States of America
57615	82	25	83	2	Energy efficiency is not just about new processes and technologies. It is also about operational practices. How about changing the Figure 11.20 title to stress improved operation, processes, and technologies?	Processes and technologies is not tied to EE but this is a good point. We will say instead "Promote new technologies and practices"		U.S. Department of State	United States of America
86721	83	4	84	19	Change all mentions to "carbon" for "greenhouse gas emission" as multilaterally agreed under the UNFCCC and its Paris Agreement.	Agreed. Revised	Government of Argentina	Ministry of Environment and Sustainable development of Argentina	Argentina
57617	83	5	84	20	The carbon price and carbon market should shed more light into carbon traded across borders and discuss mechanism like border tax adjustment, etc. The conventional carbon price and carbon market has been discussed at length and enough for years. Though still warranting mention, authors should expand to more innovative carbon pricing that also addresses embodied carbon especially in trade. About a quarter of world GHG is traded across borders. Consider recent peer-reviewed report by GEI, The Carbon Loophole in Climate Policy- Quantifying the Embodied Carbon in Traded Products. https://www.globalefficiencyintel.com/carbon-loophole-in-climate-policy The report uses the most recent available data and a cutting-edge model to conduct a global assessment of the extent of the embodied carbon in globally traded goods. GEI also published a report in 2021 on Embodied Carbon in the U.S. Manufacturing and Trade. https://www.globalefficiencyintel.com/report-embodied-carbon-in-the-us-manufacturing-and-trade	reference was added and section revised to discuss CBA a bit more		U.S. Department of State	United States of America
69887	83	5	84	19	Philibert 2017 (op. cit.) also recalls that global sectoral agreements relative to industry products internationally traded might be more realistic than global all GHG sources and sinks encompassing agreements. This option does not seem to be analysed in the chapter.	yes, however this option is not being currently discussed mainly due to the fact that countries as global agreements are highly political and may take too long to reach		Institut Français des Relations Internationales	France
86723	83	7			Change "low carbon" for "low greenhouse gas emission".	Agreed. Revised	Government of Argentina	Ministry of Environment and Sustainable development of Argentina	Argentina
63253	83	8	83	9	Would recommend updating as there are 64 carbon schemes now. https://carbonpricingdashboard.worldbank.org/	Agreed. Revised		Environment and Climate Change Canada	Canada
86725	83	11	83	20	Include if applicable "carbon taxes (including all greenhouse gas emission)"	Agreed. Revised	Government of Argentina	Ministry of Environment and Sustainable development of Argentina	Argentina
85109	83	19	83	21	Statement that only 5 countries have carbon prices above USD 40 'today' has dated - it was correct when Stiglitz et al published in 2017, but current EUA prices in the EU ETS are now above USD$40.	Agreed. Revised		Australian Industry Group	Australia
63255	83	20			61 carbon schemes are mentioned in the source above but the 2017 source mentions 58. Would recommend remaining consistent to avoid confusion	Agreed. Revised		Environment and Climate Change Canada	Canada
63257	83	21	83	22	Which industries? Does the statement encompass all emitting industries? and what are the exemptions that these industries are given. Clearer details on the exemptions would be useful.	Agreed. Revised as "emissions-intensive and trade-exposed (EITE)" industries		Environment and Climate Change Canada	Canada
85111	83	21	83	23	Statement that free allocation of emissions allowances shelters industry from price increases would be better rephrased to refer to cost increases - a crucial distinction. Selling prices are not affected by the free allocation in, for example, the EU ETS - they are shaped by international trade.	Agreed. Revised		Australian Industry Group	Australia
23275	83	25	83	28	We recommand to mention the problematic of WTO compatibility of free allowances (recently chalenged by the US DOC) and also that free allowances even tend to create incentives for beneficiaires to over-produce. REF: Kuusi, T., Björklund, M., Kaitila, V., Kokko, K., Lehmus, M., Mehling, M., ... & Wang, M. (2020). Carbon Border Adjustment Mechanisms and Their Economic Impact on Finland and the EU. Publication of the Finnish Government's analysis, assessment and research activities. Free allowances (and their over-allocation) also induce windfall profits Bruyn (de) S., Cherif S., Huigen T., & Schep E. (2016). Calculation of additional profits of sectors and firms from the EU ETS 2008-2015. ; Joltreau, E., & Sommerfeld, K. (2019). Why does emissions trading under the EU Emissions Trading System (ETS) not affect firms' competitiveness? Empirical findings from the literature. Climate policy, 19(4), 453-471. ; Hobbie, H., Schmidt, M., & Möst, D. (2019). Windfall profits in the power sector during phase III of the EU ETS: Interplay and effects of renewables and carbon prices. Journal of Cleaner Production, 240, 118066.	We mentioned that absence of GHG price can be perceived as a subsidy for fossil fuel. We also added a reference to joltreau et al.		Ministère de la Transition écologique et solidaire	France
86727	83	26			Change "carbon leakage" for "greenhouse gas emission leakage".	Agreed. Revised	Government of Argentina	Ministry of Environment and Sustainable development of Argentina	Argentina
85113	83	27	83	28	The statement that free allocation reduces the incentive to mitigate emissions is contested. Depending on the design of free allocation, emitters can still face a full price incentive to reduce emissions. If, as in the EU ETS and several other pricing regimes, free allocation to emissions intensive trade exposed industries is an output based updating allocation using an emissions intensity benchmark (best performers, industry average or otherwise), investments in emissions intensity reduction free up allocated permits for sale to others. Thus failing to reduce emissions incurs an opportunity cost at the prevailing carbon price. This nuance is critical to the design of more effective pricing regimes and should be highlighted. The work of Robert Stavins explores this design issue.	yes but the incentive is smaller compare to having to buy carbon emision allowance and thereofre the full carbon price established by the market		Australian Industry Group	Australia
87061	83	28	83	28	In addition, free allowances even tend to create incentives for beneficiaires to over-produce. Kuusi, T., Björklund, M., Kaitila, V., Kokko, K., Lehmus, M., Mehling, M., ... & Wang, M. (2020). Carbon Border Adjustment Mechanisms and Their Economic Impact on Finland and the EU. Publication of the Finnish Government's analysis, assessment and research activities. Free allowances (and their over-allocation) also induce windfall profits. Bruyn (de) S., Cherif S., Huigen T., & Schep E. (2016). Calculation of additional profits of sectors and firms from the EU ETS 2008-2015. ; Joltreau, E., & Sommerfeld, K. (2019). Why does emissions trading under the EU Emissions Trading System (ETS) not affect firms' competitiveness? Empirical findings from the literature. Climate policy, 19(4), 453-471. ; Hobbie, H., Schmidt, M., & Möst, D. (2019). Windfall profits in the power sector during phase III of the EU ETS: Interplay and effects of renewables and carbon prices. Journal of Cleaner Production, 240, 118066.	Thanks for these additional references. We used 2 of them in the Chapter.	Ministère de l'Économie, des Finances	France	
85115	83	34	84	4	The discussion of border adjustments and consumption pricing is interesting and worth including but some of the judgments expressed are contestable and the area will move fast given Europe's CBAM development. Some suggestions: The whole discussion (and indeed the segment jsut above on carbon prices) should be framed with an assessment of the significance of trade competitiveness issues. The Energy Transitions Commission's Mission Possible work, which judged that the production cost increases associated with a net zero economy were likely to be significant within supply chains but minor to end users, could be cited along with their judgment that this makes trade competitiveness concerns serious under current and expected conditions of uneven and diverse international climate policies. Production pricing with border adjustments will also provide a price signal to end users - no reason to think this is limited to explicit consumption pricing; in a market where all suppliers face a carbon price, selling prices will rise, likely to a level associated with the costs of the marginal producers needed to meet demand. Initially these may be average or higher emitters; over time lower emissions intensity, or zero emissions, production should expand and limit the ability of higher emissions producers to recover their full costs. The EU CBAM development should be briefly referenced alongside California's BCA developments.	The text has been revised and the topic of limited pass-through to end users and production pricing are both covered in the text. Even if the producing pricing will ultimately be passed to consumers, incentive will have been first given for producing mitigation measures.		Australian Industry Group	Australia
86729	83	34	84	4	To the phrases on the given lines it must be included the following clarification: "Any mechanism of the types mentioned must comply with multilaterally agreed rules under the WTO Agreements."	Agreed. Revised	Government of Argentina	Ministry of Environment and Sustainable development of Argentina	Argentina
23277	83	35	83	39	Consumption pricing does not intend to or indirectly address carbon leakage. Thus most studies building on consumption pricing do not envisage to phase-out free allowances (and these latest are the instrument reducing carbon leakage) Kuusi, T., Björklund, M., Kaitila, V., Kokko, K., Lehmus, M., Mehling, M., ... & Wang, M. (2020). Carbon Border Adjustment Mechanisms and Their Economic Impact on Finland and the EU. Publication of the Finnish Government's analysis, assessment and research activities.	Agreed. Revised so carbon pricing does not appear as a carbon leakage solution but an alternative or complementary option to CBA or free allocation		Ministère de la Transition écologique et solidaire	France
47305	83	35	83	35	are BCA and Carbon Border Adjustment / Carbon Border Adjustment Mechanismc (CBA / CBAM) the same thing?	Agreed. Revised		PBL Netherlands Environmental Assessme	Netherlands
70485	83	35	84	19	Please use the more common term "Carbon Border Adjustments" instead of the "Border Carbon Adjustments" as is being used here. Let's avoid introducing new acronyms	Agreed. Revised		European Union (EU) - DG Research &amp	Belgium
28719	83	39	83	40	In the maritime transport, efficient definition and regulation of the following can help border adjustment measures to deliver successful outputs.) 1) Entities in charge of reporting compliance with emission reduction. 2) Size and weigh thresholds for compulsory participation in the markets. Conventionally good cut-off are 5,000 gross tonnage and larger, as ships having above 5,000 gross tonnage release 85% of the global maritime GHG [(https://www.imo.org/en/MediaCentre/PressBriefings/Pages/28-MEPC-data-collection--.aspx [Ref: IMO, 2016b. New requirements for international shipping as UN body continues to address green gashouse emissions]. 3) Compliance entity point regulation, which should be downstream of the point of ship operator.	Thank you for this reference. However as it does not directly cover the industry sector we will not refer it in the text.		United Nations	Ethiopia
46133	83	39	83	40	Implementation challenges such as need of product GHG traceability and enforcement transaction cost is not only a challenge to consumption pricing, but also a challenge to border carbon adjustments for imports. The sentence here suggests that these challenges are related to consumption pricing only. (Please refer to: M. Mehling/R.Ritz (2020): Going beyond default intensities in an EU carbon border adjustment mechanism. EPRG Working Paper 2026. Cambridge Working Paper in Economics 2087. or M.Mehling, H.v. Asselt, K. Das, S. Dröge and C. Verkuijl (2019): Designing Border Carbon Adjustments for Enhanced Climate Action, in: The American Journal of International Law, Vol 113:3, p.433-481)	Revised. Added a reference.		Federal Ministry for the Environment, Nature Conservation and Nuclear Safety International Climate Policy	Germany
23279	83	41	83	41	We suggest to mention that BCA are theoretically more efficient than free allowances to reduce carbon leakage See meta-analysis from Branger, F., & Quirion, P. (2014). Would border carbon adjustments prevent carbon leakage and heavy industry competitiveness losses? Insights from a meta-analysis of recent economic studies. Ecological Economics, 99, 29-39.	the reference was added but no furhter discussion on free allowance versus Cba was addded		Ministère de la Transition écologique et solidaire	France
87063	83	41	83	41	CBAMs are theoretically more efficient than free allowances to reduce carbon leakage. See meta-analysis from Branger, F., & Quirion, P. (2014). Would border carbon adjustments prevent carbon leakage and heavy industry competitiveness losses? Insights from a meta-analysis of recent economic studies. Ecological Economics, 99, 29-39	Thanks the reference was added	Ministère de l'Économie, des Finances	France	
23281	83	44	83	44	An alternative to accurate data would be using a default value of carbon content, based on the domestic average as measured by national monitoring-reporting-verifying systems (Mehling 2019)	yes, we added a reference to CA where a default value is used		Ministère de la Transition écologique et	France
87065	83	44	83	44	An alternative to accurate data would be using a default value of carbon content, based on the domestic average as measured by national monitoring-reporting-verifying systems (Mehling 2019)	Agreed, we added a reference on this to the California use of default value	Ministère de l'Économie, des Finances	France	
23283	83	45	83	46	We recommand to rephrase the statement "principle of equal treatment" as it is more the question of the non-discrimination principle	Agreed. Revised		Ministère de la Transition écologique et	France
63259	83	47			Would recommend replacing the term "dirty production" with another term, e.g. fossil fuel production.	Agreed. Revised		Environment and Climate Change Canada	Canada
86731	84	1	84	2	Change "low carbon investment" for "low greenhouse gas emission investment".	Agreed. Revised	Government of Argentina	Ministry of Environment and Sustainable development of Argentina	Argentina
23285	84	2	84	4	The US have also implemented a border adjustment on ozone depleting chemicals (ODC)	Could not find any reference on this application of CBA		Ministère de la Transition écologique et	France
15001	84	4	84	4	Considering BCAs is not global issue for the cement sector but a topics in specific regions (EU and USA) Therefore, please either indicate reference literatures or delete the description of "and is now considering BCAs for the cement sector".	Agreed. Revised		Japan Cement Association	Japan
46135	84	5	84	13	Carbon pricing is presented in a one-sided and negative manner in this paragraph. E.g. "Carbon pricing is also criticized for promoting…": "criticised" seems to be to strong and too negative. We suggest to use the wording "Carbon pricing is also associated with promoting mainly…". and to rewrite the whole paragraph in a more balanced manner. Preferably, please replace this paragraph by a reference to the more comprehensive and thus more balanced assessment of the carbon pricing instrument in chapter 13.	modified		Federal Ministry for the Environment, Nature Conservation and Nuclear Safety International Climate Policy	Germany

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
70487	84	5	84	13	The social equity issue is not true for carbon pricing in industry. As industry has been largely exempt from carbon pricing, there exists a social equity issue exactly the other way around: most consumers find it very unfair that they have to pay for their energy while large companies are being exempt. Installing carbon taxes in industry corrects this social injustice and is therefore adding to social equity. It is important to notice this here! This point should also be made in the Summary for Policymakers. It is a general principle of deep decarbonisation that failure to address emissions in any major sector implies increasingly high (and inefficient) action in other sectors. This is true of carbon pricing both in a literal sense (e.g. an ETS) and more symbolically (where the modelled carbon price represents action that may, in the real world, be pursued through other policies).	The statement refers to cabron pricing in general. We agree with the comment and note industry exemptions in other places, including draft SPM: "...and removal of free allowances and exemptions from carbon prices would facilitate industrial transitions." No action		European Union (EU) - DG Research & Innovation	Belgium
86733	84	5			Delete in the phrase: "to achieve transformative emissions reductions" the word "transformative".	Agreed. Changed to "major"	Government of Argentina	Ministry of Environment and Sustainable development of Argentina	Argentina
63261	84	7			With respect to "difficult social acceptance of price increases": It would be interesting to provide some context of the causes behind social acceptance and what the social equity issues are. Will a price on carbon result in higher cost of living? i.e Issues concerning job loss/creation in fossil fuel/renewable energy industries and how a carbon price will affect that.	We provide elements of solutions including using the proceeds for a jut transition and developing stakeholder engagement process		Environment and Climate Change Canada	Canada
28721	84	8	84		What is then the solution to this problem? That would be helpful to the public rather than just metionning the problem.	We provide elements of solutions including using the proceeds for a jut transition and developing stakeholder engagement process		United Nations	Ethiopia
86735	84	9			Change "low carbon solutions" for "low greenhouse gas emission solutions" as indicated in previous requests.	Agreed. Revised	Government of Argentina	Ministry of Environment and Sustainable development of Argentina	Argentina
86737	84	14	84	19	When speaking about policies in this paragraph, it must be added that "Every policy implemented must comply with multilaterally agreed rules under the WTO Agreements."	Agreed. Revised	Government of Argentina	Ministry of Environment and Sustainable development of Argentina	Argentina
85117	84	18	84	19	Use of carbon price proceeds to support high abatement cost options - this could usefully refer to "support the deployment of options with near term abatement costs that are too high to be incentivised by the prevailing carbon price, but which show substantial cost reduction potential with scale and learning" or similar.	added. Thanks		Australian Industry Group	Australia
19613	84	20	84	20	Insert sentence "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 (Michaelowa et al. 2019)". Reason: The revenues from the international carbon market mechanisms were an important incentive for industrial companies to engage in mitigation. New reference: 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	reference was added		Utrecht University, Perspectives climate research, IASS-Potsdam	Germany
3749	85	1			remove "."	Agreed. Revised		Mines Saint-Etienne	France
2395	85	1	81	6	"Wesseling et al. (2017b) 1 and Bataille et al. (2018a) further add a key initial enabling step would be to conduct an ongoing stakeholder pathways process, including all stakeholders with effective "veto" power in the process (i.e. firms, unions, government, communities, indigenous groups), to gather information, educate stakeholders, debate options, and build a working consensus": This key enabling step may in fact be the death knell to get anything done. Two or three examples are below from California where the very long time it takes to get anything built from project funding inception to partial project completion is due in large part to effective veto power in the process, lawsuits, environmental reviews, NIMBYism, changing requirements and regulations: 1)High speed rail cannot be built in less than several decades and 2) large projects such as desalination plants or underground gaseous storage take a decade or more just to get permits. The key point is that there cannot be perfection where all parties can veto a project, and there probably needs to be a stronger element of top-down more authoritarian planning to realistically hit the zero carbon goal by midcentury (such as the Chinese model).	yes but too political or this chapter		Lawrence Berkeley Lab	United States of America
3751	85	2			further add that a (sentence would be easier that way)	Agreed. Revised		Mines Saint-Etienne	France
3753	85	16			ramped back, (add coma)	Agreed. Revised		Mines Saint-Etienne	France
57619	85	25			Great that voluntary commitments are included here. How about adding a text box on the Science Based Targets initiative? SBTi is the largest target-setting initiative with more than 1,200 company and financial commitments; it's value-chain oriented with scope 3 target-setting requirements; and it brings together industrial companies, financial institutions, and consumers.	this added in 11.6.4.2		U.S. Department of State	United States of America
43235	85	27	85	35	The reference to EU policy on Circular Economy needs updating. The latest policy approved in the EU is the Circular Economy Action Plan, approved in November 2020, as part of the New Green Deal. See here: https://ec.europa.eu/environment/circular-economy/	paragraph has been deleted		Zero Waste Europe/University of Manchester	United Kingdom (of Great Britain and Northern Ireland)
74909	85	27	85	40	The Kenya Green Economy Strategy and Implementation Plan 2016-2030 (GESIP) can be cited as an indication of progress in embedding the principles of sustainable development in the Country's National Growth strategy.	paragraph has been deleted		Kenya Meteorological Service	Kenya
43237	85	41	85	45	This paragraph has no references, they need adding.	paragraph has been deleted		Zero Waste Europe/University of Manchester	United Kingdom (of Great Britain and Northern Ireland)
3755	86	13			sentence seems weird to me. I would change 'will be' by 'is', But I may be wrong	Agreed. Revised		Mines Saint-Etienne	France
3757	86	29			and unique, … (add coma)	Agreed. Revised		Mines Saint-Etienne	France
29805	86	46	86	46	Please correct error. It seems that this sentence is supposed to end with "CCUS" rather than "CCU".	Agreed. Revised		Norwegian Environment Agency	Norway
57621	87	1	88	27	While these are well-written, well-referenced, and informative sections, could some examples from China be added? China is often cited as the place where new technologies are piloted, demonstrated, scaled-up, etc., (e.g. EVs, solar panels) which eventually drives down costs. There is a CCS demonstration at a cement plant in China -- Anhui Conch Cement -- for example.	Agreed. Revised		U.S. Department of State	United States of America
43935	87	2	87	24	It is critical to understand the potential carbon and enviormental implications of basic rsearch and small scale pilots before those technologies get commercialized. This point is missed in the discussion in this section. A technology focusing on reducing carbon (e.g., a new recyclign technology) does not mean it will 100% bring net carbon removal thoroughout its life cycle. What needed for basic research and pilotting (in addition to technological and funding supports) are the support from sustainability scientists who are able to provide early-stage evaluation and assessment (e.g., researchers in LCA and industrial ecology communities). The need of sustainability assessment for early-stage technologies has been well discussed in literature, and here are a few examples: (1) https://science.sciencemag.org/content/367/6476/397.abstract (2) https://www.sciencedirect.com/science/article/abs/pii/S0959652617324253	Agreed. Revised		Yale University	United States of America
2397	87	2	87	2	Basic research: on this point, if the goal is decarbonization by midcentury, it is almost impossible for a basic research innovation to be developed, debugged, transferred to a robust manufacturing process, and scaled up to meet the 2050 target, so while it may be invaluable for ~2060-2100, it won't be possible to intercept 2050. Thus, realistically, technologies that are at the later development to early commercialization stages today are the ones that are in a position to possibly intercept 2050.	Agreed. We revised to discuss applied research which is more in line with the chapter discussion of emerging identified technoloies with high potetnial for decarbonising the sector		Lawrence Berkeley Lab	United States of America
57623	88	29	95	31	This is a well-written, well-referenced, and informative section. There are a few cases where older references are used. Cite more recent literature, if possible. Also, be careful to add references to support statements throughout. There are some places where information is given without references (e.g., the County of Marin example).	added a reference for Marin and a few more recent reference.		U.S. Department of State	United States of America
85119	88	29	88	45	This section and the subsections following are excellent. However this section needs to highlight the issue of the existing spread of producer emissions intensities in different sectors. In aluminium, for instance, there is a significant share of low-emissions production already; demand for 'clean' aluminium would have to grow substantially, or be tightly defined, before it led to more than the re-allocation of existing production, with cleaner production going to buyers who care, dirtier production going to buyers who don't care, and no net effect on global sectoral emissions.	that is correct. Industrial relocation where renewable is cheap and widely availbale maybe a consequence of decarbonizing the industry.		Australian Industry Group	Australia
27843	88	31	88	32	Delete "which in many contexts even remain subsidised for the energy-intensive industries."	Agreed. Revised		Organization of the Petroleum Exporting Countries, OPEC	Austria
57625	89	25			Consider adding a new paragraph to Section 11.6.4.1: ""Within the context of carbon content certifications, other critical market infrastructure, such as regional, national, and subregional energy attribute tracking systems, which serve the important role in conveying emissions information between generators and consumers, will need to be enhanced to meet the challenges of carbon and renewable energy markets and the needs of consumers to accurately measure and manage their emissions as well as validate claims through market instruments.""	Agreed. Revised		U.S. Department of State	United States of America
57627	89	26	89	47	Authors should be aware that, while public procurement policies drawing on disclosures from Environmental Product Declarations are becoming more widely adopted, there are still efforts to make EPDs more transparent and comparable. Public procurement policies that rely on EPDs must also account for this for sound procurement decisions. Underlying assumptions of EPDs especially for upstream inputs that draw on proxies from LCI databases or industry averages may not reflect attributes of actual input. In cases where those processes contribute a significant share of the product's carbon footprint, such as cement in concrete, the embodied carbon of actual product may vary significantly from what is reported, leading to faulty assumptions on which procurement was based. Similarly, creating single industry averages for a product category, rather than project specifications, results in some subcategories being more favorable than others from a carbon standpoint though they aren't best suited for the design. This can lead to overdevelopment and depletion of limited supplies. A recent paper published on use of EPDs in pavement materials discusses recommendations. One of their findings is that, if EPDs are to be used in LCAs for comparing the environmental performance of two different product categories, harmonization of all Product Category Rules are necessary for reliable results. See https://doi.org/10.1016/j.jclepro.2020.124619	Agreed. Revised		U.S. Department of State	United States of America
57629	89	26	91	1	On green public procurement, recommend a recent report by GEI titled "Curbing Carbon from Consumption: The Role of Green Public Procurement." https://www.globalefficiencyintel.com/curbing-carbon-green-public-procurement This report looks at 30 of those programs, 22 of which are countries in Asia, Europe, North and South America, Africa, and Oceania, and five case studies at the city and regional level, as well as GPP programs of three multi-lateral banks and the UN to promote sustainable production and consumption. Fifteen of the countries reviewed are among the top 20 GHG-emitting nations. The GPP programs included in this study are at country-, state-, region-, or city-level.	Thanks. I added text and reference to the GLOBAL REVIEW OF SUSTAINABLE PUBLIC PROCUREMENT 2017 https://www.oneplanetnetwork.org/sites/default/files/globalreview_web_final.pdf		U.S. Department of State	United States of America
80397	89	26	89	27	The green Public Procurement is of paramount importance. Besides the Green Public Procurement Documents prepared by the EU the EcoDesign Regulations for a significant number of products both industrial and commercial (e.g Fans, Transformers, Ovens, etc) even white goods push the industrial sector to adopt greener processes and greener products internally or for selling. This should be pointed out as important action towards a greener industrial sector.	Agreed. Ecodesign is alerady referenced in 11.6.4.4 Mandatory Performance Standards		University of West Attica, Department of Electrical and Electronics Engineering	Greece
57631	89	32			Consider added an additional point after the Ghisetti (2017) reference: ""In some cases governments will have to provide the necessary procurement authorities and adapt government procurement policies that are not well suited for the procurement of emerging products and services that focus on the decarbonisation benefits and longer term procurement commitments (e.g., 20-year renewable energy purchases) of emissions reducing technologies and projects.""	Agreed. Revised		U.S. Department of State	United States of America
57633	89	42	89	46	Can authors address whether or not Buy Clean and similar initiatives can be expected to provide the cost incentive that these industries need to decarbonize? The cost of switching to new technology is high, and it raises the question of whether these market approaches can supply the incentive.	This addressed in 11.6.4.5 Financial Incentives		U.S. Department of State	United States of America
57635	90	1	90	34	The California Buy Clean Act is a wonderful case study, but this box is a bit too technical for the audience. It would be better to talk in broader terms about the goals and structure of the law, the constituencies affected by it, and maybe a little less detail on the EPDs and such.	Revised		U.S. Department of State	United States of America
84941	90	2	90	34	I think it's great that you did a box on Buy Clean California, as this is an extremely important policy model. However, this box is way too technical. It would be much better to use the box for a more general description of the structure of the policy, the constituencies that supported its passage, and how it is implemented.	Revised		ClimateWorks Foundation	United States of America

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
70489	91	1	91	17	What I completely miss here is the double counting issue. As Scope 1 emission of one company can be the Scope 3 emissions of another company, companies reporting on Scope 1,2 and 3 are often overestimating their emission reductions. It is important to be careful to this development as industry may end up double counting emission reductions twice.	Revised so less emphasize on Scope 3		European Union (EU) - DG Research & Innovation	Belgium
57637	91	2			Add "Scope 2 (indirect emissions from purchased electricity and steam)".	Added		U.S. Department of State	United States of America
57639	91	10			After sentence with citation for Liu et al. (2019a), consider adding: ""An example includes Microsoft Corporation which has successfully driven internal carbon-based investment through an internal carbon tax scheme."" Reference: https://unfccc.int/mfc2015/microsoft-global-carbon-fee/	Agreed. Revision were made to the text to discuss internal carbon price but no specific example was given.		U.S. Department of State	United States of America
72869	91	16	91	17	In France a reporting of emissions for most large firms is mandatory under a "social and environmental obligation" regulation and under the energy laws. This reporting includes most scope 3 emissions listed in guidelines of the Ministry. This is a weak obligation but still represent a mandatory reporting. Maybe add "currently nearly no obligation for firms to report scope 3 emissions" or similar	Added a sentence about this		EE-Consultant	France
57641	91	17			Add the follow imperative: ""It will be critically important that the corporate accounting frameworks, standards, and related guidance (e.g., GHG Protocol) be maintained to reflect the evolving needs and innovations in the global market and to maintain voluntary management of emissions as a significant market driver."" Reference: https://ghgprotocol.org/	Agreed. Revised		U.S. Department of State	United States of America
74911	91	19	91	32	The Minimum Energy Performance standard(MEPS) that quide the testing and labelling of appliances recently developed and adopted in Kenya can be cited in this section.	In this sentence we are refering to standards that relate to low-carbon metrics for the industry sector. The recent MEPS developed in Kenya related to energy used in the building sector and therefore should be referenced in Chapter 9 - Buildings		Kenya Meteorological Service	Kenya
70491	91	26	91	26	I don't believe that 25% of emissions of a building (over lifetime) are due to the materials that have been used to construct it - that's really an outragous number for buildings that often last over 40 years. I tried to look up this study, but the reference in the literature list returned me an error. Please revise statement and make sure that the reference is adequate.	The text has been corrected as well as the reference.		European Union (EU) - DG Research & Innovation	Belgium
2399	91	33	91	45	It's important to note that is it important to move from energy intensity limits (energy/m2) to carbon intensity and ultimately to absolute limites on life cycle CO2 and GHG rather than intensity metrics since 1) the planet doesn't care about energy intensity or carbon intensity but net GHG emissions; and 2) intensity metrics can lead to unintended consequences e.g. developers may want to build larger developments since lower energy intensity (energy/m2) is easier to achieve in larger buildings. Similarly, there is no penalty for single family homes in the US to be McMansion-sized if their energy intensity is meeting code.	ok, this is covered in Chapter 5- Demand, services and social aspects of mitigation		Lawrence Berkeley Lab	United States of America
43983	91	42	91	48	Regarding mandatory performance standards, I agree that a global lifecycle analysis (LCA) metric is needed. EPDs are not a sufficient standard for building materials because EPDs limit their LCA to "cradle-to-gate" analysis of the product, ignoring the lifecycle impacts and benefits of the selected material and products during the use and post-use phases – critical considerations when making building decisions and formulating long-term climate policy.This system is particularly problematic when EPDs are used to compare different materials rather than just suppliers. Finally, EPDs only tell part of the story of a specific product's broader social impact because other benefits, like resilience, durability, heat resistance, adaptability to climate change, and ability to be a carbon sink may be excluded. I would recommend a LCA metric for building materials based upon consensus-based standards (e.g., ASTM, ISO, etc.)	Thanks		Portland Cement Association	United States of America
57643	91	48			Consider adding the following for further context: ""Further research is needed to understand how different international and national frameworks, codes, and standards that focus on emissions can work in unison rather than in opposition to amplify their mutually desired outcomes. Building performance and market instrument trading frameworks recognized globally do not always incentivize the same outcomes due to the differences in market approach.""	Agreed. Revised		U.S. Department of State	United States of America
77795	92	2	92	30	Reference should be made to new and innovating financial market contracts for basic materials that represent low-carbon varieties of conventional materials, and such contracts tend to trade at a premium (the "green premium") to the non-green contracts. The primary example to date is the London Metal Exchange's introduction of a "green aluminum" spot exchange contract, which delivers only low-carbon aluminum products. As such it is expected that such a green-aluminum contract would trade at a premium to the base aluminum contract, providing a financial incentive to producers and value chain participants for the low-carbon variety of aluminum. See https://www.lme.com/-/media/Files/About/Responsibility/LME-Sustainability-Discussion-Paper.pdf?la=en-GB	Agreed. Revised		Climate Wedge LLC	United States of America
2401	92	39	92	41	"at current rates of 85% above 60% and 43%" - this phrase and sentence is unclear.	Agreed. Revised		Lawrence Berkeley Lab	United States of America
3541	92	41	92	41	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".	Revised accordingly		IECA	Spain
10433	92	41	92	41	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".	Revised accordingly		Oficemen	Spain
11589	92	41	92	41	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".	Revised accordingly		UNIVERSITY	Spain
74913	93	4	93	31	The section should also consider the need to strengthen the quadriple Helix collaboration particularly in the developing countries. where the private Sector, research institutions, Civil society, media work together to deliver demand driven research.This approach is weak in Developing Countries	Revised. Added a reference.		Kenya Meteorological Service	Kenya
70493	93	4	93	31	This paragraph is not particularly well developed, it merely points at one issue (organisational routines for learning) and could probably be integrated wiith 11.7 (knowledge gaps).	We disagree. The section speaks broadly about the need for new knowledge and capacity to address this new governance challenge. No action		European Union (EU) - DG Research &amp	Belgium
2403	93	34	93	35	"An industrial net-zero transition, while technically feasible with small advancements in our current technological capability": wait, why are only small advancements needed in technological capability. I disagree that only small advancements are needed in decarbonizing iron and steel and chemicals in particular. There is such as wide range of product types and performance needs for these sectors and others, that claiming we are mostly there in technological capability is stretching credulity.	Ok, revised.		Lawrence Berkeley Lab	United States of America
3759	93	40			Global Comment : for future reports, you should consider more largely decision aiding approaches. as we are focused on CO2, we may loose sight on other environmental impacts, and hence, we are dealing with multicriteria decision making. Roy 1996 for instance, but a lot of people deal with this issue and are not represented in your report... B. Roy, Multicriteria Methodology for Decision Aiding, vol. 12. Boston, MA: Springer US, 1996.	This is addresses in the paragraph above in this sentence: "This transition must also link decarbonisation to larger environmental and social goals (e.g. air and water quality, low GHG growth, poverty alleviation, sustainable development goals) (OECD 2019b)"		Mines Saint-Etienne	France
47307	94	6	94	6	Please spell out the core message that is implied in the UKCCC net-zero technical report - all information needs to be synthesized into the AR6 report (no referals)	revised		PBL Netherlands Environmental Assessme	Netherlands
12041	94	7	94	8	The text should note (either here or perhaps in section 12.3.2) that currently the transportation of captured CO2 across state boundaries is precluded. This is one of several challenging governance issues which needs to be addressed if the CCS indicated in the text is to be realised. Specifically, Article 6 of the London Convention/protocol creates a de-facto ban on transboundary transport of CO2 for geological storage, potentially limiting capacity for CCS or CDR if they rely on carbon sequestration in a second country. Although Parties agreed an amendment to resolve this issue in 2009, only eight of the 53 Parties have ratified it and a two thirds majority is required before the amendment can enter into force. This is one of several challenging governance issues which need to be addressed if the CCS indicated in the chapter can ever be achieved. It would be helpful to reference both the specific point, but also the wider governance challenges for the uptake and delivery of the safe, permanent sequestration of carbon. See HUBERT, A.-M. 2020. International Legal and Institutional Arrangements relevant to the Governance of Climate Engineering Technologies'. In: FLORIN, M.-V. (ed.) International Governance of Climate Engineering. Information for policymakers Lausanne: EPFL International Risk Governance Center (IRGC).	We now acknowledge this issue but using a more recent reference that states: Therefore in 2019, Contracting Parties to the London Protocol adopted a Resolution to allow provisional application of an amendment to Article 6 of the Protocol to allow export of CO2 for storage in sub-seabed geological formations. New reference file:///C:/Users/Lars%20J/Downloads/SSRN-id3820609.pdf Exporting CO2 for Offshore Storage – The London Protocol's Export Amendment		Carnegie Climate Governance Initiative (C2G) - The Carnegie Council for Ethics and International Affairs	United Kingdom (of Great Britain and Northern Ireland)
17861	94	7	94	8	Pipelines are not the only means of CO2 transportation. CO2 transportation infrastructure includes transporting CO2 with ships, barges, trucks and trains. Resources: 1) https://www.ipcc.ch/site/assets/uploads/2018/03/srccs_chapter4-1.pdf 2) ICEF 2020 Roadmap: Biomass Carbon Removal and Storage (BiCRS) https://www.icef-forum.org/roadmap/ 3) https://www.iea.org/reports/ccus-in-clean-energy-transitions/ccus-technology-innovation	Ok, revised.		Global CCS Institute	Belgium
60485	94	9	94	11	This statement is outdated. Numerous Life Cycle Analysis have shown the potential of CCU technologies and this is today not anymore the main barrier for the deployment of these technologies. The chances for these CCU technologies to succeed will strongly	This comment does not seem to relate to the statement made on lines 9-11. No action		Université Libre de Bruxelles / CO2 Value Europe	Belgium
78823	94	9	94	11	This statement is outdated. Numerous Life Cycle Analysis have shown the potential of CCU technologies and this is today not anymore the main barrier for the deployment of these technologies.	This comment does not seem to relate to the statement made on lines 9-11. No action		CEA	France
83729	94	9	94	11	This statement is outdated. Numerous Life Cycle Analysis have shown the potential of CCU technologies and this is today not anymore the main barrier for the deployment of these technologies. The chances for these CCU technologies to succeed will strongly	This comment does not seem to relate to the statement made on lines 9-11. No action		LUT University	Finland
85121	94	9	94	11	Worth noting that reformed hydrogen may be from coal as well as gas; that electrolysis hydrogen will also require water resources, and that all hydrogen options imply significant new or adapted infrastructure for H2 storage, distribution and use.	Ok, revised.		Australian Industry Group	Australia
70495	94	18	94	20	Please notice that these numbers as % of GDP are on the high side when compared to the numbers produced in Chapter 15. Probably it would be better to refer here to Chapter 15.	Ok, revised.		European Union (EU) - DG Research & Innovation	Belgium
27845	94	27	95	13	The option of carbon circular economy (CCE) could also be considered, as recently adopted by G20 countries. The CCE approach can apply the concept of the 3Rs, adding another strategy (remove) as a new component.	Revised		Organization of the Petroleum Exporting Countries, OPEC	Austria
60487	95	22	95	22	Please use use CCU and CCS in place of CCUS to be coherent with the rest of the report.	Revised		Université Libre de Bruxelles / CO2 Value	Belgium
78825	95	22	95	22	Please use CCU and CCS in place of CCUS to be coherent with the rest of the report.	Revised		CEA	France
83731	95	22	95	22	Please use use CCU and CCS in place of CCUS to be coherent with the rest of the report.	Revised		LUT University	Finland
37267	95		95		New mention - GHG Emissions should be restricted by the per capita GHG emission (Global Average) value.	not sure what is the comment relating to. No action		Bhabha Atomic Research Centre Trombay Mumbai	India
37269	95		95		New mention - CDR plant for each industry / plant should be made compulsory.	Added to table: Require net-zero strategies in permitting		Bhabha Atomic Research Centre Trombay Mumbai	India
57645	97	1	97	37	Are there any knowledge gaps that pertain to developing or emerging economies? The experiences and literature in general and the experiences and literature cited in the chapter are heavily based on Western experiences.	Heavy industry is typically multinational and new plants in developing countries are typically state of the art		U.S. Department of State	United States of America
57647	97	10	97	13	Energy efficiency is continual, not just incremental. Consider adding: ""In addition to continued efforts to increase the use of known, but often under-utilized, strategies such as energy efficiency and electrification, transformational change is required in the industry sector. There is limited knowledge of the ability to implement such transformational change effectively with sufficient flexibility in switching pathways, as for some options technology readiness levels are currently low.""	Agree, will amend, although should be noted that EE-potentials in energi intensive industry are limited compaed to other sub-sectors		U.S. Department of State	United States of America
82821	97	14	97	17	to address this knowledge gap, it would be good somewhere to suggest investments in better models and datasets as well as more cross-collaborations between the IAM community and other domains, like LCA, IE, civil engineers, inventors, etc. to generate better data and inform better modelign decisions. With the increased focus on industrial decarbonization, policy makers should be aware that there is a lot of analytical capacity building needed, too, that has faced lots of historical barriers	Thank you. Will revise accordingly		Northwestern University	United States of America
85123	97	24	97	29	What is meant by "packaged mitigation policies"? Disagree that free allocation measures have sheltered industry from carbon price incentives - they have largely been designed to preserve such incentives, and so should be able to be judged on outcomes so far. Correct "industrial lobbing" at line 28 to industrial lobbying".	This will be clarified		Australian Industry Group	Australia

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
47309	97	28	97	28	"Lack of industrial lobbying' needs further elaboration - I am not quite sure what the authors mean exactly.	Clarified: Lobbying against climate policy, diluting, or demanding overcompensation		PBL Netherlands Environmental Assessme	Netherlands
57649	97	31		37	The policies that focus market pull (creating demand) have been lacking. For many developing countries, there are also significant co-benefits on air quality and health that can be a key driver as well. Lastly, the lifecycle based material resource need and infrastructure need for full decarbonization of industry or electrification should be assessed.	Thanks, this will be noted		U.S. Department of State	United States of America
2405	97	39	97	39	One FAQ question could be, "what happens to the oil and gas industry?". This topic or question at the least should be raised in the Industry chapter's sections on pathways, transitions, existing infrastructure, if it does not already. Thank you.	This is a good point. Too late to make big changes in FAQ but we will consider this for earlier sections.		Lawrence Berkeley Lab	United States of America
46491	97	41	98	2	FAQ 11.1: please avoid phrasing sentences in the "we"-perspective. The text should be generally applicable to any reader.	Thanks, will revise		Federal Ministry for the Environment, Nature Conservation and Nuclear Safety International Climate Policy	Germany
57651	98	1	98	3	Renewable energy will be needed for other sectors of the economy (i.e., transportation and the electrical grid) to decarbonize and may compete in some instances.	Reject. Word count does not allow this detail		U.S. Department of State	United States of America
74243	98	1	98	1	Revise this sentence to strike "renewable" and insert "carbon free" to reflect the role that clean non-renewable generation including nuclear and hydro among others will play in meeting the future demand for fossil free industrial production.	Will add "or other carbon-free"		Pillsbury Law Firm	United States of America
46137	98	3	98	3	Please change sentence: " Apart from mechanical recycling, this can include chemical recycling of plastics…" Reasoning: Chemical recycling is not yet a standard state of the art technology and its environmental benefit is not yet proven. (References: https://www.umweltbundesamt.de/sites/default/files/medien/5750/publikationen/hgp_chemischesrecycling_englisch_bf.pdf; https://www.vivis.de/wp-content/uploads/WM9/2019_WM_359-370_Quicker.pdf; https://www.nabu.de/imperia/md/content/nabude/abfallpolitik/zwe_jointpaper_understandingenvironmentalimpactsofcr_en.pdf)	Will indicate this		Federal Ministry for the Environment, Nature Conservation and Nuclear Safety International Climate Policy	Germany
5533	98	8	98	8	replace Renewables" by "low carbon sources"	Will add "or other carbon-free"		Retraité/ Pdt d'association	France
9371	98	10	98	12	Asking two closed questions and then responding "The answer is both yes and no" might not be the best way to attract readers' attention. My suggestion would be to ask "How can costs arising from industrial decarbonisation be reduced and synergies with sustainable development be increased/created?"	Thank you. This is a good suggestion.		Helmholtz Centre Geesthacht	Germany
9373	98	12	98	12	Please replace "it" by "industrial decarbonisation" for clarity (if this is what is meant here).	Thanks. Good suggestion		Helmholtz Centre Geesthacht	Germany
57653	98	14	98	15	Add energy efficiency to this list also. Most energy efficiency measures pay back in ~ 5 years from energy savings then continue to return cost savings throughout their lifetimes.	Yes, thank you for spotting this		U.S. Department of State	United States of America
46493	98	19	98	20	FAQ 11.2: the explanation is very vague concerning the solutions, e.g. it does not elaborate on how it might be possible to achieve reduced demand for services. Please elaborate more on potential solutions.	Word count does not allow elaboration here but we will look elsewhere in the chapter to do this		Federal Ministry for the Environment, Nature Conservation and Nuclear Safety International Climate Policy	Germany
60489	98	23	98	24	I would add at the end of this sentence the importance to base decisions on holistic Life Cycle Analysis results when it comes to the deployment of these technologies. •Zimmerman et al., 2018 , CO2 Chem Media and Publishing Ltd.	Good point but it fits better under knowledge gaps		Université Libre de Bruxelles / CO2 Value Europe	Belgium
83733	98	23	98	24	I would add at the end of this sentence the importance to base decisions on holistic Life Cycle Analysis results when it comes to the deployment of these technologies. •Zimmerman et al., 2018 , CO2 Chem Media and Publishing Ltd.	Same comment		LUT University	Finland
9375	98	26	98	36	The question does not sound as if it can be answered in 10 lines of text. My suggestion would be to define a clearer focus for this FAQ and highlight it in the question: Is this FAQ about multi-faceted strategies and coordination across domains? Is it about the development of novel materials, products and production processes? Is it about the importance of a strong policy framework?	It is about all three aspects. Only smaller changes to FAQs are possible at this point		Helmholtz Centre Geesthacht	Germany
46495	98	26	98	36	FAQ 11.3: there are strong overlaps with FAQ 11.1. Please consider merging FAQ 11.1 and FAQ 11.3.	Will calibrate 11.3 more towards policy and 11.1 more towards options		Federal Ministry for the Environment, Nature Conservation and Nuclear Safety International Climate Policy	Germany
85595	99	10	99	12	First author name is missing.	Same as Åhman above. All references will be looked at		Environmental Conservation Department,	Myanmar
57655	113	34			If an organization is not known to everyone, need to provide its full name instead of its abbreviation. For example, IRP should be given its full name "International Resource Panel".	Whole chapter will be edited including for abbreviations	Government of United States of America	U.S. Department of State	United States of America
43903					Figure 11.4, lines are hard to see and the lengend of each line may need full-name spelled somewhere for readers to understand the assumptions and meaning of each scenario	Figures will be redrawn	Government of United States of America	Yale University	United States of America
43905					Table 11.4, does the column "GHG Reduction" represent the net GHG reduction that takes GHG emissions emited by the technology its (e.g.. GHG emissions due to energy demand of capture capture process itself)? Some clarifications here may be helpful	It's the multiplciative reduction ascribeb by the referenced literature.	Government of United States of America	Yale University	United States of America
43907					Table 11. 2 may want to include research and educational institutes as a actor who provides training and education for cultiving future workforce needed by a low/zero-carbon economy. Research and educational insitutes are also a source of innovation to develop advanced technologies for industrial decarbonization.	Noted	Government of United States of America	Yale University	United States of America
43909					Figure 11.9 is a little bit confusing. I guess the quoted content in each bubble is just one example of strategy under each category? For example, product material efficiency should have different strategies for different materials, rather than only including those related to concrete. I suggest making it more clear in the figure caption that each strategy included in the figure is just an example for each category.	Fig 11.10 and the preceding table are to harmonized and moved ot the end of 11.4.	Government of United States of America	Yale University	United States of America
57657					The writing quality and clarity of this chapter is inconsistent. The writing clarity and language for the pages 1 through approximately 12 could be improved with editing to make it clearer and easier to read and comprehend.	Thank you. All will be edited for language and consistency	Government of United States of America	U.S. Department of State	United States of America
57671					The entire chapter is hard to follow and difficult to read. Someone needs to edit the document for readability as well as basic grammatic errors. The chapter has more of the feel of an academic paper on modeling results than a policy report on the state of industrial GHG emissions and options for decarbonization.	See above	Célia Sapart	U.S. Department of State	United States of America
57683					This chapter uses phrases like "supply chain", "value chain", and "innovation chain" indiscriminantly. In reality, these systems are complicated and multi-dimensional -- more like networks. It might make more sense to talk about "supply networks" and "innovation networks" instead.	This will be checked and changed to calue networks where suitable	Christian Breyer	U.S. Department of State	United States of America
57659					The energy efficiency strategy should cover sub-topics like energy support systems efficiency (e.g., steam, process heating, and motor driven systems), smart manufacturing, combined heat and power, and strategic energy management (ISO 50001). The chapter doesn't cover all these sub-topics and needs some organization. The current discussion on energy efficiency strategy also fails to clearly address topics like: (a) R&D opportunities to improve existing energy efficiency technologies and barriers for implementation, (b) enablers and barriers discussed from both energy efficiency opportunities and policy perspective, and (c) energy efficiency pathways/pillars potential for reduction quantified by each individual industrial sector.	Revised.	Government of United States of America	U.S. Department of State	United States of America
57663					The write-up on energy efficiency strategy should try to reference the following references and reports: 1. UK GOV: Industrial Decarbonization and Energy Efficiency Roadmaps to 2050. This report addresses questions like: - Current emissions from each sector and how is energy used? - Business environment, strategies of companies, investment decisions in decarbonization? -- Enablers and barriers - Baseline levels of energy and emissions change over the period to 2050? -- Scenarios - Potential to reduce emissions in these sectors until 2050? -- Pathways and scenarios - Pathways each sector follows over the period to 2050 under different scenarios? -- Pathways and scenarios - Next steps required by industry, the government, and others to overcome the barriers to achieve pathways? 2. ACEEE: Halfway There: Energy Efficiency Can Cut Energy Use and Greenhouse Gas Emissions in Half by 2050. Steve Nadel & Lowell Ungar, September 2019, Report U1907- updates to previous reports from 2012 and 2016. This report concludes that: - 11 opportunities presented if pursued aggressively could reduce 2050 energy use and carbon emissions by almost half (50%) - Achieving these savings will require aggressive policies and investments including rapid upgrades to standards, improvements to existing factories, adoption of new industrial process and systems, electrification, etc. - Policies for industrial efficiency are not well defined. More attention is needed to develop policies that will spur energy savings and emission reductions. - Continued RD&D to identify and validate new EE measures. Essential to drive cost down. 3. Study of Energy Efficiency and Energy Saving Potential in Industry and on Possible Policy Mechanisms - EU - ICF International. This report includes: - Energy consumption profile for all sectors in different scenarios (2013 as the base year consumption) through 2050 - Study evaluated over 230 ESOs and screened each one of them for economic viability based on simple payback approach - Savings analysis by industries and individual energy savings measures and their potential and projected energy consumption - Energy intensity trends for each individual sectors presented through 2050 - Internal and technical barrier for uptake of ESO's for each sector - Proposed policy measures in regards to EU policy context. - EnMS standards (ISO 50001) potential and analysis with metrics discussed 4. CHP Potential for Carbon Emission Reductions, National Assessment 2020 - 2050; ICF Report for Energy Solutions Center. The summary of this report is: - CHP system fueled by NG are expected to continue reducing carbon emissions through 2050. - Additionally, RNG and Biogas has the potential to be introduced to reduce emissions even further. - Role of CHP in a low carbon future and grid impacts - Daytime CHP displaces mostly top of the stack fossil (peaking and intermediate) - 24/7 CHP -- emissions from mix of fossil fuel resources - Marginal generators in the U.S currently on fossil fuels as renewables and nuclear do not have the ability to respond to changes in load. 5. Enhancing operational performance and productivity benefits in breweries through smart manufacturing technologies, Journal of Advanced Manufacturing and Processing, 2020. This article uses case studies to demonstrate the potential of smart manufacturing (SM) and Internet of Things (IoT) technologies to enhance operational performance and productivity in industry. The analysis highlights benefits such as cost reduction, production flexibility, shorter product time-to-market, energy/water efficiency and environmental impact reduction, and increased productivity.	Thanks. Used some references from this comments.	Government of United States of America	U.S. Department of State	United States of America
57665					The chapter has a very technology-specific focus that missed the importance of system optimization within plants and across supply chains. It is important to remember that the industrial sector is very complex and interconnected, and that it will be important not only to shift manufacturing technologies to low-carbon alternatives, but also look to optimize these systems and supply chain for decarbonization. IIoT/Industry 4.0/Smart Manufacturing affords opportunities for visibility and optimization of these complex systems.	Under circular economy we discuss industrial symbiosis and digitalistion under energy efficiency	Government of United States of America	U.S. Department of State	United States of America
57667					The characterization of energy efficiency is very limited and takes a static view of this important decarbonization pathway. While the chapter characterizes the energy efficiency as a mature pathway, this area is evolving rapidly, enabled by sensor, communications and simulation capabilities. Energy management as manifested by strategic energy management and ISO-50001 is forming an important organizational foundation for energy and emissions optimization and creating organizational infrastructure that can enable accelerated adoption of new transformative technologies such as electrification and low-carbon fuels.	Technology such as sensor has developed indeed. But importance of energy management has been recognised for long and such progress of technology and EM are in different dimmension. ISO-50001 was included.	Government of United States of America	U.S. Department of State	United States of America
57669					The discussion of energy efficiency in Section 11.3.4 is disorganized and unfocused and misses many important opportunities. This section should be redrafted to provide a more robust characterization of this pathway. There is a note that energy efficiency was covered in AR5, but energy efficiency has evolved in the intervening years. In addition, it is important to note that energy efficiency to minimize energy consumption may produce different outcomes from an approach that focuses on decarbonization. Some efforts, such as by the U.S. Department of Energy, are beginning to make this shift in focus as directed by the U.S. House of Representatives Select Committee on the Climate Crisis (https://climatecrisis.house.gov/report). It will be important for policymakers to encourage and support this shift in focus.	Revised.	Government of United States of America	U.S. Department of State	United States of America

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
57673					The authors want to focus primarily on new concepts like the circular economy and material efficiency, which are important, but it's a mistake to not include more discussion on energy efficiency. Simply stating that the WGIII AR5 talked about energy efficiency is not helpful for understanding the different policy options available. It seems to dismiss the topic when it is what most people are focused on in the near term. The energy efficiency section is thin and misses several important points and recent trends: - There is still a lot of potential for increased energy efficiency - Improving thermal efficiencies is going to be increasingly important for reducing direct emissions over the next 10-15 years - Fuel switching to electric can improve the efficiency of some systems, but it will become more important to use electricity efficiently as demand for renewable electricity grows.	Importance of EE will be further stressed in various places but still refer to AR5	Célia Sapart	U.S. Department of State	United States of America
57675					This chapter is information-rich; however, the text spends excessive space on discussion of material efficiency and technical solutions with insufficient discussion of sector pathways and 2050 "residual emissions" for net-zero frameworks, equity and human impacts of industrial sector mitigation, and financial sector links (including R&D investment, capital for mitigation implementation, and sustainability-linked loans, among other new climate-related financial products).	These aspects will be strengthened in section 11.6	Célia Sapart	U.S. Department of State	United States of America
57677					Suggest creating a table similar to Table 11.6 to the Executive Summary to help illustrate the role different strategies (EE, ME, CE, CCS, etc.) play in industrial decarbonization.	Not suitable for ES but table or graphics will be considered for TS	Célia Sapart	U.S. Department of State	United States of America
57679					It might be useful to point out that one effect of improving material efficiency is to reduce the availability of steel scrap. Use scrap could have climate benefits (e.g., Scrap-to-EAF production has a much lower energy-intensity compared to BF-BOF production route).	Reject: ME incudes a range of strategies, some which have different effects on scrap availability. For example, increasing the life time of products reduces EOL scrap, however, it also reduces overall replacement demand at the same time, so the effect is not noticed. Improving manufacturing yield reduces home scrap, however alos reduces the required throughput for remelting. In each case, it can be argued with a system view, that ME has no effect on the overall balance.	Pramod K. Singh	U.S. Department of State	United States of America
57681					Industry 4.0 has been discussed briefly in Section 11.3.4.2. However, its role and potential for mitigating climate change has not been fully assessed or highlighted at all in the Executive Summary. This is a major deficiency in this chapter since it is supposed to focus on new options and developments since AR5. In the fight against climate change, Industry 4.0, 5G, and the Internet of Things can play a significant role. According to the Information Technology Industry Council (https://www.itic.org/policy/energy/intelligent-efficiency), for example, if the United States were to take advantage of currently available intelligent industry opportunities, the U.S. could reduce energy use by about 12-22% and realize tens or hundreds of billions of dollars in energy savings and productivity gains. Intelligent industry helps optimize manufacturing processes, discover energy waste that might otherwise go unnoticed, create a smart energy management system, build intelligent supply chain operations, achieve data-driven preventive maintenance, optimize operation under a connected workforce, and so on.	We will strengthen this discussion but the reference provided is not for industry specifically.	Philippe Tulkens	U.S. Department of State	United States of America
60501					The role of CO2-based fuels also called synthetic fuels, e-fuels or powerfuels is acknowledged in the chapter 6, but the related references and major statements do not reflect the state-of-the-art of the literature on this subject. In the current version, CO2-based fuels are not considered as drop-in solutions and their deployment is considered as unlikely in the near to mid-term. This statement does not reflect the technology advancements presented in the recent literature nor the readiness level of numerous CO2 to fuel projects all over the world. To give a concrete example, the first flight using e-kerosene has started flying early 2021 in the Netherlands (https://www.transportenvironment.org/news/first-passenger-flight-performed-using-clean-fuels-sort). CO2-based fuels can find a role in sectors that are harder to decarbonize, such as aviation, shipping and energy intensive industries since hydrocarbons have volumetric energy densities that are orders of magnitude above those of hydrogen and present-day batteries (e.g. Dimitriou et al., 2015, Schmidt et al., 2017, Hepburn et al., 2019, DENA-Powerfuels in Aviation, 2019). The long-term use of carbon based energy carriers in a net zero emissions economy relies upon their production with renewable energy, and upon low-cost, scalable, clean hydrogen production, e.g. 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 CO2-based fuels have sizeable market shares, due to cost reductions and policy drivers (Hepburn et al., 2019). In the near-term (2030), the CO2 used to produced alternative fuel will mainly come from point sources (e.g. Farfan et al.,2019), while in the mid-term (2040), it will come from direct air capture (DAC) (RAM et al., 2020, Breyer et al., 2019, Drechsler and Agar, 2021). Life-cycle analysis demonstrate that both point source and DAC to fuel pathways can provide climate benefit over conventional diesel fuel if a low carbon source of electricity is used (e.g.Daggash et al., 2018, CONCAWE, 2019, Liu et al., 2020,). The chances for these CO2-based fuels to succeed will strongly depend on their compatibility with existing technology and infrastructure, with the growth and price of renewable energy and with the development of appropriate policy and market incentives (Grim et al., 2020). Despite these challenges, most of the boundary conditions (fuel composition, price, feedstock) for near- and medium-term deployment of CO2-based fuels are clear; now, it is a matter of finding the most economical route towards the synthesis of these fuels (Ramirez et al., 2020). In term of technologies, recent advances in the CCU field offer untapped potential for the realization of CO2 conversion to fuels. Today, a large palet of technologies exist, some are close to commercialization, others are at the benchtop/pilot scale, and some have yet to be scientifically proven. Thermochemical and bioelectrochemical routes offer the most technically feasible near-term opportunities for CO2-based fuels, representing immediately deployable pathways to high-value and relatively high-volume products. These pathways are the closest to commercialization and are ready to be upscaled in near-term (5-10 years) while other routes such as the direct electrochemical pathways are promising on the long-term but will take several decades to overcome the current technical barriers (Diaz et al., 2018, Messias et al. 2019, Edwards et al., 2019, Bushuyev et al., 2020, Masel et al., 2021). Close to 50 high Technology Readiness Level (TRL) projects on CO2 to fuel exist in Europe and many of them will reach commercialisation in the near-term (before 2030). Please find a few examples below with the forecasted production of CO2-based fuel in near-term (within 5 years): -Norsk-efuel (DAC to jet-fuel)=> 100 Million ton of jet-fuel/year -Carbon Recycling International => 4000 tons of methanol/year -Jupiter 1000 (CO2 flue gas to CH4) : 25Nm3/h of methane -North CCUhub (CO2 to methanol)=> 44000 tons of methanol/year -Mo-Industrial e-fuel (CO2 to methanol)=> 80 000 tons of methanol/year -C2Fuel (CO2 to formic acid) => 2.4 Million tons of formic acid/year -Audi e-gas plant (CO2 to methane => 1000 tons of methane/year The high cost of CCU technologies is often considered as a drawback for the upscaling of these technologies. However, De Luna et al, 2019 have shown that when electricity costs fall below 4 cents/kWh and energy efficiency is at least 60%, all products generated from CO2 electrolysis will become competitive with current market prices for these products derived from fossil fuel sources. REFERENCES: Masel et al. Nature Nanotechnology, 2021, 16, 118-128. •Drechsler and Agar 2021, International Journal of Greenhouse Gas Control 105, 103230.•Dimitrou et al., 2015, Energy Environ. Sci, 8, 1775-1789.•Hepburn et al., 2019, Nature, 575, 87-97.•Schmidt et al., 2017, Chem. Ing. Tech. 2018, 90, o. 1–2, 127–140.•DENA, 2019, Powerfuels in Aviation, German Energy Agency •Messias et al. Reaction Chem. &Eng. , 2019, 4, 1982-1990.•Bushuyev et al., 2018, Joule, 2(5), pp.825-832.•Diaz et al. Green Chem., 2018, 20, 620-626.•Edwards et al. Applied Energy , 2019, 261, 114305.•Daggash et al., 2018, Sustainable Energy Fuels, 2, 1153-1169.•Farfan et al., 2019, J. Clean Prod., 217, 821-835•CONCAWE, 2019: A look into the role of e-fuels in the transport system in Europe (2030–2050) (literature review), CONCAWE. •Ramirez et al., 2020, Trends in Chemistry, 2-9, Pages 785-795.•Liu et al., 2020, Sustainable Energy Fuels, 4, 3129-3142.•Breyer et al., 2019, Joule, 3, 2053-2057.	This subject is addressed at length in 11.3.6 and table 11.4. I would have like to add additional references from this comment, but insufficient information for the papers was provided, e.g. the DOI address.	Christian Breyer	Université Libre de Bruxelles / CO2 Value Europe	Belgium
60503					The role of CO2-based fuels also called synthetic fuels, e-fuels or powerfuels is acknowledged in the IPCC AR6 WGIII SOD, but the related references and major statements do not reflect the state-of-the-art of the literature on this subject. In the current version of chapter 11, CO2-based fuels are not clearly stated as drop-in solutions to deffosilise the industry and their deployment is considered as unlikely in the near to mid-term. This statement does not reflect the technology advancements presented in the recent literature nor the readiness level of numerous CO2 to fuel projects all over the world. To give a concrete example, the first flight using e-kerosene has started flying early 2021 in the Netherlands (https://www.transportenvironment.org/news/first-passenger-flight-performed-using-clean-fuels-sort). CO2-based fuels can find a role in sectors that are harder to decarbonize, such as aviation, shipping and energy intensive industries since hydrocarbons have volumetric energy densities that are orders of magnitude above those of hydrogen and present-day batteries (e.g. Dimitriou et al., 2015, Schmidt et al., 2017, Hepburn et al., 2019, DENA-Powerfuels in Aviation, 2019). The long-term use of carbon based energy carriers in a net zero emissions economy relies upon their production with renewable energy, and upon low-cost, scalable, clean hydrogen production, e.g. 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 CO2-based fuels have sizeable market shares, due to cost reductions and policy drivers (Hepburn et al., 2019). In the near-term (2030), the CO2 used to produced alternative fuel will mainly come from point sources (e.g. Farfan et al.,2019), while in the mid-term (2040), it will come from direct air capture (DAC) (RAM et al., 2020, Breyer et al., 2019, Drechsler and Agar, 2021). Life-cycle analysis demonstrate that both point source and DAC to fuel pathways can provide climate benefit over conventional diesel fuel if a low carbon source of electricity is used (e.g.Daggash et al., 2018, CONCAWE, 2019, Liu et al., 2020,). The chances for these CO2-based fuels to succeed will strongly depend on their compatibility with existing technology and infrastructure, with the growth and price of renewable energy and with the development of appropriate policy and market incentives (Grim et al., 2020). Despite these challenges, most of the boundary conditions (fuel composition, price, feedstock) for near- and medium-term deployment of CO2-based fuels are clear; now, it is a matter of finding the most economical route towards the synthesis of these fuels (Ramirez et al., 2020). In term of technologies, recent advances in the CCU field offer untapped potential for the realization of CO2 conversion to fuels. Today, a large palet of technologies exist, some are close to commercialization, others are at the benchtop/pilot scale, and some have yet to be scientifically proven. Thermochemical and bioelectrochemical routes offer the most technically feasible near-term opportunities for CO2-based fuels, representing immediately deployable pathways to high-value and relatively high-volume products. These pathways are the closest to commercialization and are ready to be upscaled in near-term (5-10 years) while other routes such as the direct electrochemical pathways are promising on the long-term but will take several decades to overcome the current technical barriers (Diaz et al., 2018, Messias et al. 2019, Edwards et al., 2019, Bushuyev et al., 2020, Masel et al., 2021). Close to 50 high Technology Readiness Level (TRL) projects on CO2 to fuel exist in Europe and many of them will reach commercialisation in the near-term (before 2030). Please find a few examples below with the forecasted production of CO2-based fuel in near-term (within 5 years): -Norsk-efuel (DAC to jet-fuel)=> 100 Million ton of jet-fuel/year -Carbon Recycling International => 4000 tons of methanol/year -Jupiter 1000 (CO2 flue gas to CH4) : 25Nm3/h of methane -North CCUhub (CO2 to methanol)=> 44000 tons of methanol/year -Mo-Industrial e-fuel (CO2 to methanol)=> 80 000 tons of methanol/year -C2Fuel (CO2 to formic acid) => 2.4 Million tons of formic acid/year -Audi e-gas plant (CO2 to methane => 1000 tons of methane/year The high cost of CCU technologies is often considered as a drawback for the upscaling of these technologies. However, De Luna et al, 2019 have shown that when electricity costs fall below 4 cents/kWh and	This subject is addressed at length in 11.3.6 and table 11.4	Christian Breyer	Université Libre de Bruxelles / CO2 Value Europe	Belgium

Comment ID	From Page	From Line	To Page	To Line	Comment	Response	Reviewer Name	Reviewer Affiliation	Reviewer Country
60515					Carbon Capture and Utilisation (CCU) is now considered as a solution to mitigate climate change in the IPCC AR6 WGIII SOD, however its definition and several key messages need to be refined to reflect the literature. CCUS is barely used anymore, but CCU and CCS are still mixed sometimes, especially when discussing the barriers and needs of CCS, which does not do good to CCU as the barriers and needs are not the same. CCU technologies are available now and offer solutions to reduce net CO2 emissions with an estimated potential impact of gigatons equivalent CO2 emissions. Indeed, CCU technologies have the potential to utilize up to 8 Gt of CO2 per year by 2050 (GCI, 2016, Hepburn et al., 2019), this is equivalent to approximately 15% of current global CO2 emissions. Moreover, When CO2 is captured directly and stored permanently via mineralization into building materials, CCU can also create negative emissions (e.g.Di Maria et al., 2020, Ostovari et al., 2020). Unlike other options, CCU technologies provide drop-in solutions which can be implemented without requiring significant modification of existing production, distribution and use infrastructure (e.g. Ampelli et al., 2015, Hepburn et al., 2019). Another important asset of CCU technologies is the utilisation of CO2 as carbon feedstock to replace fossil resources (e.g. Sternberg et al., 2017, Daggash et al., 2018, Kätelhön, et al., 2019, Thonemann, 2019) and support the development of a circular economy, e.g. when CO2 is used together with industrial wastes to create materials (e.g. Di Maria et al., 2020, Ostavari et al., 2020). CCU technologies have the potential to provide solutions to hard-to-abate sectors, but also to generate revenues through producing marketable products (e.g. Hepburn et al., 2019, Zhu, 2019). Because of their lack of granularity, Integrated Assessment Models (IAM's) have yet failed in simulating the complexity of the different CCU options to realize net zero or negative CO2 emissions (e.g. Detz and Zwaan, 2019). Consequently, no exhaustive quantification exists today on the climate mitigation potential of this large panel of technologies. However, their key role should be considered as one building block in a portfolio of mitigation measures (e.g. Wilson et al., 2016, GCI, 2016, Grüber et al., 2018, IEAGHG, 2019b, Detz and Zwaan, 2019). Following the CCU concept, CO2 can be captured at point sources or directly from the atmosphere and subsequently converted into valuable products such as building materials, chemicals, synthetic fuels (e.g. Styring et al., 2011; von der Assen et al., 2013, SAPEA, 2018, Kätelhön et al., 2019). The duration of the CO2 storage into a product strongly varies from days to millenia according to the applications. However, in term of environmental assessment, CCU technologies should not be assessed only with respect to the amounts of CO2 that can be used nor to its storage duration, but rather it is essential to determine the life cycle of the CO2-based product generated (e.g. Bruhn et al., 2016, Zimmerman et al., 2018, Nocito and DiBenedetto al., 2020). If these products are assumed to be substitutes for fossil-based products and thus provide the same service (i.e. it would be used and disposed of according to the same patterns as conventional products), the focus of the life-cycle-analysis may lie in the cradle-to-gate phase (e.g. Kätelhön, et al., 2019). Two important points should however be highlighted (Arning et al., 2019, IEAGHG, 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. CO2 has already been used for decades with mature technologies in various industrial processes such as the food and beverage industry, urea production, water treatment and the production of fire retardants and coolants. But there are now many new CCU technologies at various stages of development from R&D to commercialization stage (e.g. about 60 large-scale projects at high Technology Readiness Level are currently ongoing in Europe and will reach commercialization in the near-term. Some examples are: North CCU Hub, Norsk e-fuel, STEELANOL, JUPITER 1000, INITIATE, C2Fuel, Carbon2Chem, CO2Fokus,	We reviweed this comment, and the core contributions are already covered at length in 11.3.6 and table 11.4	Christian Breyer	Université Libre de Bruxelles / CO2 Value Europe	Belgium
60519					In Chapter 11, the role of CO2 as a potential feedstock for the chemical industry, production of plastic, materials etc. is not discussed clearly, but it should be considered as a solution to defosilize the chemical industry and to decrease its carbon footprint. Chemical production is set to become the single largest driver of global oil consumption by 2030. To reduce oil consumption and resulting greenhouse gas emissions, CO2 can be captured from point sources or from the air and utilized as alternative carbon feedstock for chemicals. Carbon capture and utilisation (CCU) has the technical potential to decouple chemical production from fossil resources, reducing annual GHG emissions by up to 3.5 Gt CO2-eq in 2030 (Katelön et al., 2019). CCU technologies can substitute the conventional production of various chemicals including basic chemicals, fine chemicals, and polymers (Kondratenko et al., 2013, Centi et al., 2013, Klankermayer et al., 2015, Cuéllar-Franca and Azapagic, 2015, Sternberg et al., 2017, Al-Mamoori et al., 2017, Adalco et al., 2019). Today, 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 (Jarvis et al., 2018). For the production of polymers, the utilisation 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 may sequester CO2 for decades or even centuries (Geyer et al., 2017, Hepburn et al., Nature, 2019). 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. However, formic acid produced via hydrogenation and polyol production are the conversion technologies with the highest potential for reducing the climate impact from a consequential life cycle perspective (Benett et al., 2014, Thonemann and Pizzol., 2019, Müller et al., 2020). Large amounts of renewable energy is required to transform CO2 into useful chemicals. However, it is possible to turn this limitation into an opportunity, by using the process of converting CO2 to higher energy density compounds as an effective way to insert renewable electricity and hydrogen into the chemical production chain. The storage and transport of CO2-based fuels does not require changes of infrastructure and is less expensive than the transport and storage of hydrogen. The use of CO2 conversion to exploit unused renewable energy resources or to mitigate instabilities on the grid (related to the discontinuous production of energy by renewable sources; thus, chemical conversion is a way to store and distribute energy) will play a future relevant role (e.g.Ampelli et al., 2017, IEAGHG2019a,b, Grim et al., 2020) *Aldaco et al., 2019, Science of the Total Environment, 663, 738-753. •Al-Mamoori et al., 2017, Energy Technol (Weinheim) 5:834–849 •Centi et al., 2013, Energy Environ, Science, 6:1711.•Cuéllar-Franca and Azapagic, 2015, J.CO2.Utili., 9, 82-102.•Kätelhön et al., 2019: Climate change mitigation potential of carbon capture and utilization in the chemical industry, PNAS, 116, 23, 11187-11194.•Sternberg et al., 2017, Green Chemistry, 9.•Hepburn et al., 2019, Nature, 575, 87-97.•Geyer et al., 2017, Science Adv. 3.•Jarvis and Samsatli, 2018, Sustain.Energy.Rev, 85, 46-48.•IEAGHG, 2019a: Putting CO2 to Use – Creating value from emissions, International Energy Agency. •IEAGHG, 2019b: Exploring Clean Energy Pathways: the role of energy storage, International Energy Agency.•Ampelli et al., 2015, Phil.Trans.R.Soc.A, 373.•Grim et al., 2020, Energy & Environmental Science, 13(2), pp.472-494.•Benett et al., 2014, Energy Procedia 63, 7976–7992.•Thonemann and Pizzol., 2019, Energy Environ. Sci., 12, 2253.•Müller et al., 2020, frontiers in Energy Research, 8:15.•Thonemann, 2019, Applied Energy, 263, 114599.	CCU, carbon sourcing vs CCS will be revised	Government of France	Université Libre de Bruxelles / CO2 Value Europe	Belgium
67513					Enabling role of systemic corporate strategies including regenerative and conscious capitalism, new conception of transparency, collaborative and constructive lobbying for decarbonization and dematerialization is the big omission in the chapter.	Corporate responsibilities is explicitly addressed in 11.6.4.2	Richard Bohan	Institute of Rural Management Anand	India
70497					All carbon used in a net-zero world will have to be cyclical. This means either using biomass or DAC as feedstock; using fossil fuels and feedstocks but ensuring 100% capture at end of life with full, lossless reuse or requestration; or using fossil fuels and feedstocks and offsetting any emission. Given the widely recognized difficulties in the realization of large scale negative emissions and the limited CO2 storage potential, consider clearly including the limitations and caveats of CCS and CCUS from fossil CO2.	Yes, this should be clear	Richard Bohan	European Union (EU) - DG Research & Innovation	Belgium
83745					The role of CO2-based fuels also called synthetic fuels, e-fuels or powerfuels is acknowledged in the chapter 6, but the related references and major statements do not reflect the state-of-the-art of the literature on this subject. In the current version, CO2-based fuels are not considered as drop-in solutions and their deployment is considered as unlikely in the near to mid-term. This statement does not reflect the technology advancements presented in the recent literature nor the readiness level of numerous CO2 to fuel projects all over the world. To give a concrete example, the first flight using e-kerosene has started flying early 2021 in the Netherlands (https://www.transportenvironment.org/news/first-passenger-flight-performed-using-clean-fuels-sort). CO2-based fuels can find a role in sectors that are harder to decarbonize, such as aviation, shipping and energy intensive industries since hydrocarbons have volumetric energy densities that are orders of magnitude above those of hydrogen and present-day batteries (e.g. Dimitriou et al., 2015, Schmidt et al., 2017, Hepburn et al., 2019, DENA-Powerfuels in Aviation, 2019). The long-term use of carbon based energy carriers in a net zero emissions economy relies upon their production with renewable energy, and upon low-cost, scalable, clean hydrogen production, e.g. 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 CO2-based fuels have sizeable market shares, due to cost reductions and policy drivers (Hepburn et al., 2019). In the near-term (2030), the CO2 used to produced alternative fuel will mainly come from point sources (e.g. Farfan et al.,2019), while in the mid-term (2040), it will come from direct air capture (DAC) (RAM et al., 2020, Breyer et al., 2019, Drechsler and Agar, 2021). Life-cycle analysis demonstrate that both point source and DAC to fuel pathways can provide climate benefit over conventional diesel fuel if a low carbon source of electricity is used (e.g.Daggash et al., 2018, CONCAWE, 2019, Liu et al., 2020,). The chances for these CO2-based fuels to succeed will strongly depend on their compatibility with existing technology and infrastructure, with the growth and price of renewable energy and with the development of appropriate policy and market incentives (Grim et al., 2020). Despite these challenges, most of the boundary conditions (fuel composition, price, feedstock) for near- and medium-term deployment of CO2-based fuels are clear; now, it is a matter of finding the most economical route towards the synthesis of these fuels (Ramirez et al., 2020). In term of technologies, recent advances in the CCU field offer untapped potential for the realization of CO2 conversion to fuels. Today, a large palet of technologies exist, some are close to commercialization, others are at the benchtop/pilot scale, and some have yet to be scientifically proven. Thermochemical and bioelectrochemical routes offer the most technically feasible near-term opportunities for CO2-based fuels, representing immediately deployable pathways to high-value and relatively high-volume products. These pathways are the closest to commercialization and are ready to be upscaled in near-term (5-10 years) while other routes such as the direct electrochemical pathways are promising on the long-term but will take several decades to overcome the current technical barriers (Diaz et al., 2018, Messias et al. 2019, Edwards et al., 2019, Bushuyev et al., 2020, Masel et al., 2021). Close to 50 high Technology Readiness Level (TRL) projects on CO2 to fuel exist in Europe and many of them will reach commercialisation in the near-term (before 2030). Please find a few examples below with the forecasted production of CO2-based fuel in near-term (within 5 years): -Norsk-efuel (DAC to jet-fuel)=> 100 Million ton of jet-fuel/year -Carbon Recycling International => 4000 tons of methanol/year -Jupiter 1000 (CO2 flue gas to CH4) : 25Nm3/h of methane -North CCUhub (CO2 to methanol)=> 44000 tons of methanol/year -Mo-Industrial e-fuel (CO2 to methanol)=> 80 000 tons of methanol/year -C2Fuel (CO2 to formic acid) => 2.4 Million tons of formic acid/year -Audi e-gas plant (CO2 to methane => 1000 tons of methane/year The high cost of CCU technologies is often considered as a drawback for the upscaling of these technologies. However, De Luna et al, 2019 have shown that when electricity costs fall below 4 cents/kWh and energy efficiency is at least 60%, all products generated from CO2 electrolysis will become competitive with current market prices for these products derived from fossil fuel sources. REFERENCES: Masel et al. Nature Nanotechnology, 2021, 16, 118-128. •Drechsler and Agar 2021, International Journal of Greenhouse Gas Control 105, 103230.•Dimitrou et al., 2015, Energy Environ. Sci, 8, 1775-1789.•Hepburn et al., 2019, Nature, 575, 87-97.•Schmidt et al., 2017, Chem. Ing. Tech. 2018, 90, o. 1–2, 127–140.•DENA, 2019, Powerfuels in Aviation, German Energy Agency •Messias et al. Reaction Chem. &Eng. , 2019, 4, 1982-1990.•Bushuyev et al., 2018, Joule, 2(5), pp.825-832.•Diaz et al. Green Chem., 2018, 20, 620-626.•Edwards et al. Applied Energy , 2019, 261, 114305.•Daggash et al., 2018, Sustainable Energy Fuels, 2, 1153-1169.•Farfan et al., 2019, J. Clean Prod., 217, 821-835•CONCAWE, 2019: A look into the role of e-fuels in the transport system in Europe (2030–2050) (literature review), CONCAWE. •Ramirez et al., 2020, Trends in Chemistry, 2-9, Pages 785-795.•Liu et al., 2020, Sustainable Energy Fuels, 4, 3129-3142.•Breyer et al., 2019, Joule, 3, 2053-2057.	Overall revisions and amendments will be made to CCU discussion, including caveats	Richard Bohan	LUT University	Finland

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83747					The role of CO_2-based fuels also called synthetic fuels, e-fuels or powerfuels is acknowledged in the IPCC AR6 WGIII SOD, but the related references and major statements do not reflect the state-of-the-art of the literature on this subject. In the current version of chapter 11, CO_2-based fuels are not clearly stated as drop-in solutions to deffosilise the industry and their deployment is considered as unlikely in the near to mid-term. This statement does not reflect the technology advancements presented in the recent literature nor the readiness level of numerous CO_2 to fuel projects all over the world. To give a concrete example, the first flight using e-kerosene has started flying early 2021 in the Netherlands (https://www.transportenvironment.org/news/first-passenger-flight-performed-using-clean-fuels-sort). CO_2-based fuels can find a role in sectors that are harder to decarbonize, such as aviation, shipping and energy intensive industries since hydrocarbons have volumetric energy densities that are orders of magnitude above those of hydrogen and present-day batteries (e.g. Dimitriou et al., 2015, Schmidt et al., 2017, Hepburn et al., 2019, DENA-Powerfuels in Aviation, 2019). The long-term use of carbon based energy carriers in a net zero emissions economy relies upon their production with renewable energy, and upon low-cost, scalable, clean hydrogen production, e.g. via the electrolysis of water. The estimated potential for the scale of CO_2 utilization in fuels varies widely, from 1 to 4.2 Gt CO_2 yr^{-1}, reflecting uncertainties in potential market penetration. The high end represents a future in which CO_2-based fuels have sizeable market shares, due to cost reductions and policy drivers (Hepburn et al., 2019). 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Despite these challenges, most of the boundary conditions (fuel composition, price, feedstock) for near- and medium-term deployment of CO_2-based fuels are clear; now, it is a matter of finding the most economical route towards the synthesis of these fuels (Ramirez et al., 2020). In term of technologies, recent advances in the CCU field offer untapped potential for the realization of CO_2 conversion to fuels. Today, a large palet of technologies exist, some are close to commercialization, others are at the benchtop/pilot scale, and some have yet to be scientifically proven. Thermochemical and bioelectrochemical routes offer the most technically feasible near-term opportunities for CO_2-based fuels, representing immediately deployable pathways to high-value and relatively high-volume products. 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Nature Nanotechnology, 2021, 16, 118-128. •Drechsler and Agar 2021, International Journal of Greenhouse Gas Control 105, 103230.•Dimitrou et al., 2015, Energy Environ. Sci, 8, 1775-1789.•Hepburn et al., 2019, Nature, 575, 87-97.•Schmidt et al., 2017, Chem. Ing. Tech. 2018, 90, o. 1–2, 127–140.•DENA, 2019, Powerfuels in Aviation, German Energy Agency •Messias et al. Reaction Chem. &Eng. , 2019, 4, 1982-1990.•Bushuyev et al., 2018, Joule, 2(5), pp.825-832.•Diaz et al. Green Chem., 2018, 20, 620-626.•Edwards et al. Applied Energy , 2019, 261, 114305.•Daggash et al., 2018, Sustainable Energy Fuels, 2, 1153-1169.•Farfan et al., 2019, J. Clean Prod., 217, 821-835•CONCAWE, 2019: A look into the role of e-fuels in the transport system in Europe (2030–2050) (literature review), CONCAWE. •Ramirez et al., 2020, Trends in Chemistry, 2-9, Pages 785-795.•Liu et al., 2020, Sustainable Energy Fuels, 4, 3129-3142.•Breyer et al., 2019, Joule, 3, 2053-2057.	Same comment	Richard Bohan	LUT University	Finland
83759					Carbon Capture and Utilisation (CCU) is now considered as a solution to mitigate climate change in the IPCC AR6 WGIII SOD, however its definition and several key messages need to be refined to reflect the literature. CCUS is barely used anymore, but CCU and CCS are still mixed sometimes, especially when discussing the barriers and needs of CCS, which does not do good to CCU as the barriers and needs are not the same. CCU technologies are available now and offer solutions to reduce net CO_2 emissions with an estimated potential impact of gigatons equivalent CO_2 emissions. Indeed, CCU technologies have the potential to utilize up to 8 Gt of CO_2 per year by 2050 (GCI, 2016, Hepburn et al., 2019), this is equivalent to approximately 15% of current global CO_2 emissions. Moreover, When CO_2 is captured directly and stored permanently via mineralization into building materials, CCU can also create negative emissions (e.g.Di Maria et al., 2020, Ostovari et al., 2020). Unlike other options, CCU technologies provide drop-in solutions which can be implemented without requiring significant modification of existing production, distribution and use infrastructure (e.g. Ampelli et al., 2015, Hepburn et al., 2019). Another important asset of CCU technologies is the utilisation of CO_2 as carbon feedstock to replace fossil resources (e.g. Sternberg et al., 2017, Daggash et al., 2018, Kätelhön, et al., 2019, Thonemann, 2019) and support the development of a circular economy, e.g. when CO_2 is used together with industrial wastes to create materials (e.g. Di Maria et al., 2020, Ostavari et al., 2020). CCU technologies have the potential to provide solutions to hard-to-abate sectors, but also to generate revenues through producing marketable products (e.g. Hepburn et al., 2019, Zhu, 2019). Because of their lack of granularity, Integrated Assessment Models (IAM's) have yet failed in simulating the complexity of the different CCU options to realize net zero or negative CO_2 emissions (e.g. Detz and Zwaan, 2019). Consequently, no exhaustive quantification exists today on the climate mitigation potential of this large panel of technologies. However, their key role should be considered as one building block in a portfolio of mitigation measures (e.g. Wilson et al., 2016, GCI, 2016, Grüber et al., 2018, IEAGHG, 2019b, Detz and Zwaan, 2019). Following the CCU concept, CO_2 can be captured at point sources or directly from the atmosphere and subsequently converted into valuable products such as building materials, chemicals, synthetic fuels (e.g. Styring et al., 2011; von der Assen et al., 2013, SAPEA, 2018, Kätelhön et al., 2019). The duration of the CO_2 storage into a product strongly varies from days to millenia according to the applications. However, in term of environmental assessment, CCU technologies should not be assessed only with respect to the amounts of CO_2 that can be used nor to its storage duration, but rather it is essential to determine the life cycle of the CO_2-based product generated (e.g. Bruhn et al., 2016, Zimmerman et al., 2018, Nocito and DiBenedetto al., 2020). If these products are assumed to be substitutes for fossil-based products and thus provide the same service (i.e. it would be used and disposed of according to the same patterns as conventional products), the focus of the life-cycle-analysis may lie in the cradle-to-gate phase (e.g. Kätelhön, et al., 2019). Two important points should however be highlighted (Arning et al., 2019, IEAGHG, 2019b, Zhu, 2019): 1)If CO_2-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 CO_2 in the products. 2)If CO_2-based products are recycled i.e. if their end of life CO_2 emissions are captured to generate new products, the duration of CO_2 storage in a product is not anymore crucial to consider in the life cycle analysis. CO_2 has already been used for decades with mature technologies in various industrial processes such as the food and beverage industry, urea production, water treatment and the production of fire retardants and coolants. But there are now many new CCU technologies at various stages of development from R&D to commercialization stage (e.g. about 60 large-scale projects at high Technology Readiness Level are currently ongoing in Europe and will reach commercialization in the near-term. Some examples are: North CCU Hub, Norsk e-fuel, STEELANOL, JUPITER 1000, INITIATE, C2Fuel, Carbon2Chem, CO2Fokus, COLUMBUS). Some examples of already commercialised CCU technologies: Carbon8Systems (Uk), Climeworks (Switzerland), Carbon Upcycling (Canada), Covestro (Germany), Orbix (Be), Lanzatech (US), UR One (Canada), Carbon Recyclng International (Iceland).	CCUS will not be used as a concept. CCU sections will be revised in light of various (and conflicting) comments.	Emilio Minguez	LUT University	Finland
83759					(continuing)The capture and conversion of CO_2, especially into chemicals and fuels, use important amount of renewable energy which is often considered as a drawback to consider these technologies. However, the prices of the different renewable energy options as well as an adequate evaluation of the future evolution of these prices 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, Ram et al., 2020). Moreover, it is important to note that CCU can foster the transition towards renewable energy via the power-to-X approach, i.e. with the production of synthetic fuels/e-fuels to store energy (e.g. Sternberg and Bardow, 2015, Ram et al., 2019, Breyer et al., 2015, 2019, Fasihi et al., 2017, 2019, Anwar et al., 2020). In term of public acceptance, no public discourse exist about CCU technologies to date (Jones et al. 2015, van Heek 2018). However, Carbon Capture and Storage (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 CO_2-based technologies (L'Orange Seigo et al., 2014; Brühn et al., 2016; 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). In the current context where the environmental and social externalities of incumbent fossil based technologies are not fully integrated in market prices, the speed of the commercial deployment of innovative CCU solutions will largely depend on the development of a strong supportive policy framework, composed of regulations and market incentives (e.g.ICEF, 2017, SAM, 2018, IEAGHG, 2019b, Zhang et al., 2020). Broad policy and regulatory changes that may support the appropriate scale-up of CO_2 utilization include creating carbon prices of around \$40 to \$80 per tonne of CO_2, increasing over time, to penalize CO_2 emissions and to incentivize verifiable CO_2 emissions reductions and removals from the atmosphere (Hepburn et al., 2019). It is crucial to foster demand for and competitiveness of climate neutral, circular economy solutions through demand-side measures, but also to investigate and develop alternative or complementary options for carbon pricing mechanisms considering their impact on emissions, markets and investments at all levels. (HLEG on EIE, 2019).•Aldaco et al., 2019, Science of the Total Environment, 663, 738-753. •Al-Mamoori et al., 2017, Energy Technol (Weinheim) 5:834–849. •Ampelli et al., 2015, Phil.Trans.R.Soc.A, 373. •Anwar et al., 2020, J. of Env. Manag., 260, 110059. •Arning et al. 2019, Energy Policy, 125, 235–249. •Artz et al., 2019, Chem. Rev., 118, 2, 434-504. •Benett et al., 2014, Energy Procedia 63, 7976–7992. •Beuttler et al., 2019, Frontiers n Climate, 1 :10. •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. •Bushuyev et al., 2018, Joule, 2(5), pp.825-832. •CCES, 2019: Carbon Utilization – A vital and effective pathway for decarbonization, Center for Climate and Energy Solutions. •Centi et al., 2013, Energy Environ, Science, 6:1711. •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.				

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83759					(continuing) •Cuéllar-Franca and Azapagic, 2015, J.CO2.Utili., 9, 82-102. •Daggash et al., 2018, Sustainable Energy Fuels, 2, 1153-1169. •De Luna et al., 2019, Science, 364, 6438. •DENA, 2019, Powerfuels in Aviation, German Energy Agency •Detz and Zwaan, 2019, Energy Policy, 133, 110938. •Deutz et al., 2018, Energy Environ. Sci., 11, 331. •Diaz et al. Green Chem., 2018, 20, 620-626. •Di Maria et al, 2020, International Journal of Greenhouse Gas Control, 93. •Dimitrou et al., 2015, Energy Environ. Sci, 8, 1775-1789. •Drechsler and Agar 2021, International Journal of Greenhouse Gas Control 105, 103230. •Ebrahimi et al., 2017, J. of Cleaner Production, 156, 660-669. •Edwards et al. Applied Energy , 2019, 261, 114305. •Farfan et al., 2019, J. Clean Prod., 217, 821-835. •Fasihi et al., 2017, J. of Cleaner Production, 224, 957-980. •Fasihi et al., 2019, Journal of Cleaner Productions, 224, 957-980. •GCI, 2016: Global Roadmap Study of CO2U Technologies, LUX Research & Global CO2 Initiative. •Giannoulakis et al., 2014, International Journal of GHG Control, 21, 140-157. •Gumber and Gurumoorthy, 2018, Methanol, Chap. 25, 661-675. •Geyer et al., 2017, Science Adv. 3. •Grim et al., 2020, Energy & Environmental Science, 13(2), pp.472-494. •Grüber et al, 2018: A low energy demand scenario for meeting the 1.5 C target and sustainable development goals without negative emission technologies', Nature Energy, 3, 6. •Haegel et al., 2019, Science, 364, 836-838. •Hepburn et al., 2019, Nature, 575, 87-97. •Hills et al., 2020, frontiers in Energy Research, 8 :142. •HLEG on EII, 2019: Masterplan for a Competitive Transformation of EU EII Enabling a Climate-neutral, Circular Economy by 2050, High Level Expert Group on Energy Intensive industries. •Huang et al., 2019, J. of Cleaner Production, 241, 118359. •ICEF, 2017: Carbon dioxide Utilization Roadmap 2.0, Innovation and Cool Earth Forum (ICEF). •IEAGHG, 2019a: Putting CO2 to Use – Creating value from emissions, International Energy Agency. •IEAGHG, 2019b: Exploring Clean Energy Pathways: the role of energy storage, International Energy Agency. •Jarvis and Samsatli, 2018, Sustain.Energy.Rev, 85, 46-48. •Jones et al. 2015, Faraday Discussions, 183: 327-347				
83759					(continuing) •Kaliyavaradhan et al., 2017, J. CO2. Utili., 20, 234-242. •Kätelhön et al., 2019, PNAS, 116, 23, 11187-11194. •Khoo et al., 2011, Energy Procedia, 4, 2494-2501. •Kirchoffer et al., 2013, Energy Procedia, 37, 5858-5869. •Klankermayer and Leitner, 2015, Science 350, 629–630. •Kondratenko et al., 2013, Energy Environ Science, 6:3112. •Krey et al., 2019, Energy, 172, 1254-1267. •Lee et al., 2020, J. CO2. Util., 37, 113-121. •Liu et al., 2020, Sustainable Energy Fuels, 4, 3129-3142. •L'Orange Seigo et al., 2014, Int. J. Greenh. Gas. Control 25, 23–32. •L'Orange Seigo et al., 2014, Renew. Sustain. Energy Rev. 38, 848–863. •Masel et al. Nature Nanotechnology, 2021, 16, 118-128. •Messias et al. Reaction Chem. &Eng. , 2019, 4, 1982-1990. •Müller et al., 2020, frontiers in Energy Research, 8:15. •Muratori et al., 2018, Energies 2018, 11, 1171. •NAS, 2019, Negative Emissions Technologies and Reliable Sequestration, The National Academies Press. •Nocito and Dibenedetto, 2020, Current Opinion in Green and Sustainable Chemistry, 21, 34–43. •Ostadi et al., 2019, Biomass and Bioenergy, 127, 105282. •Ostovari et al., 2020, Sustainable Energy Fuels, 4, 4482-4496. •Pan et al., 2020, Nature Scientific Reports 7, 17227. •Pasquier et al., 2018, Geosciences, 8(9), 342. •Perdan et al., 2017, Sustain. Prod. Consum. 10, 74–84. •Ram et al., 2020 DENA/LUT University report, Powerfuels in Renewable Energy Word. •Ramboll, 2019, The Institute for Advanced Sustainability Studies CESR, CEDelft and IOM Law. •Ramirez et al., 2020, Trends in Chemistry, 2-9, Pages 785-795. •SAM, 2018: Novel carbon capture and utilisation technologies, Scientific Advice Mechanism (SAM), Independent scientific advice for policy making. •SAPEA, 2018, Science Advice for Policy by EU Academies, Novel Carbon Capture and Utilisation Technologies-Research and Climate Aspects, Evidence Review Report, 2. •Schmidt et al., 2017, Chem. Ing. Tech. 2018, 90, o. 1–2, 127–140. •Schemme et al., 2017, Fuel, 205, 198-221. •Shih et al., 2018, Joule, 2, 1925-1949.				
83759					(continuing) •Sternberg and Bardow, 2015, Energy Environ. Sci. 8, 389–400. •Sternberg et al., 2017, Green Chemistry, 9. •Styring et al., 2011, Carbon Capture and Utilization in the Green Economy. Centre for Low Carbon Futures, York. •Tam et al., 2020, Construction and building Materials, 250, 118903. •Thonemann and Pizzol., 2019, Energy Environ. Sci., 12, 2253. •Thonemann, 2019, Applied Energy, 263, 114599. •Tripathi et al., 2020, Nature Scientific Report, 10:958. •Van Heek et al, 2017, Energy Proc., 114, 7212–7223. •Vartiainen et al., 2019, Progress in Photovoltaics, Wiley, 1-15. •Viebahn et al., 2019, Energies, 12, 3443. •Von der Assen et al., 2013, Energy Environ. Sci. 6, 2721–2734. •Wich et al. 2020, Frontiers Energy Research, 7, 162. •Wilson et al., 2016: A strategic european research and innovation agenda for Smart CO2 Transformation in Europe. Smart CO2 Transformation (SCO2T) project 978-0-9572588-5-3. •Zevenhoven and J . Fagerlund, 2010, Mineralisation of carbon dioxide (CO2), 433-462, 16, Åbo Akademi University, Finland, Woodhead Publishing Limited. •Zimmerman et al., 2018 , CO2 Chem Media and Publishing Ltd. •Zhang et al., 2020, Renewable and Sustainable Energy Reviews, 117, 109495				
83763					In Chapter 11, the role of CO2 as a potential feedstock for the chemical industry, production of plastic, materials etc. is not discussed clearly, but it should be considered as a solution to defosilize the chemical industry and to decrease its carbon footprint. Chemical production is set to become the single largest driver of global oil consumption by 2030. To reduce oil consumption and resulting greenhouse gas emissions, CO2 can be captured from point sources or from the air and utilized as alternative carbon feedstock for chemicals. Carbon capture and utilisation (CCU) has the technical potential to decouple chemical production from fossil resources, reducing annual GHG emissions by up to 3.5 Gt CO2-eq in 2030 (Katelön et al., 2019). CCU technologies can substitute the conventional production of various chemicals including basic chemicals, fine chemicals, and polymers (Kondratenko et al., 2013, Centi et al., 2013, Klankermayer et al., 2015, Cuéllar-Franca and Azapagic, 2015, Sternberg et al., 2017, Al-Mamoori et al., 2017, Adalco et al., 2019). Today, 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 (Jarvis et al., 2018). For the production of polymers, the utilisation 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 may sequester CO2 for decades or even centuries (Geyer et al., 2017, Hepburn et al., Nature, 2019). 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. However, formic acid produced via hydrogenation and polyol production are the conversion technologies with the highest potential for reducing the climate impact from a consequential life cycle perspective (Benett et al., 2014, Thonemann and Pizzol., 2019, Müller et al., 2020). Large amounts of renewable energy is required to transform CO2 into useful chemicals. However, it is possible to turn this limitation into an opportunity, by using the process of converting CO2 to higher energy density compounds as an effective way to insert renewable electricity and hydrogen into the chemical production chain. The storage and transport of CO2-based fuels does not require changes of infrastructure and is less expensive than the transport and storage of hydrogen. The use of CO2 conversion to exploit unused renewable energy resources or to mitigate instabilities on the grid (related to the discontinuous production of energy by renewable sources; thus, chemical conversion is a way to store and distribute energy) will play a future relevant role (e.g.Ampelli et al., 2017, IEAGHG2019a,b, Grim et al., 2020) *Aldaco et al., 2019, Science of the Total Environment, 663, 738-753. •Al-Mamoori et al., 2017, Energy Technol (Weinheim) 5:834–849 •Centi et al., 2013, Energy Environ, Science, 6:1711.•Cuéllar-Franca and Azapagic, 2015, J.CO2.Utili., 9, 82-102.•Kätelhön et al., 2019: Climate change mitigation potential of carbon capture and utilization in the chemical industry, PNAS, 116, 23, 11187-11194.•Sternberg et al., 2017, Green Chemistry, 9.•Hepburn et al., 2019, Nature, 575, 87-97.•Geyer et al., 2017, Science Adv. 3.•Jarvis and Samsatli, 2018, Sustain.Energy.Rev, 85, 46-48.•IEAGHG, 2019a: Putting CO2 to Use – Creating value from emissions, International Energy Agency. •IEAGHG, 2019b: Exploring Clean Energy Pathways: the role of energy storage, International Energy Agency.•Ampelli et al., 2015, Phil.Trans.R.Soc.A, 373.•Grim et al., 2020, Energy & Environmental Science, 13(2), pp.472-494.•Benett et al., 2014, Energy Procedia 63, 7976–7992.•Thonemann and Pizzol., 2019, Energy Environ. Sci., 12, 2253.•Müller et al., 2020, frontiers in Energy Research, 8:15.•Thonemann, 2019, Applied Energy, 263, 114599.	Yes, revisions will be made in light of many CCU comments	Michael Grubb	LUT University	Finland