Response to reviewer 1

Thank you opportunity to review global carbon budget. I conclude authors have submitted (another) excellent product. Comprehensive and careful compilations and analysis, great graphics, excellent presentation (other ESSD papers should emulate Tables 1, 2 and 3), easy- to-access and easy-to-use spreadsheet. Thanks to authors and thanks to ESSD.

I make a few comments about confusing organization and also (mindful of admonition from editor to find ways to shorten) a few suggestions on ways to shorten. Overall, I enthusiastically recommend publication.

Thank you.

1) Abstract, exec summary, introduction, etc. I suppose authors might intend abstract and introduction for other scientific users, as for many ESSD papers, with executive summary for non-experts? Reader now confronts abstract of three paragraphs, with middle paragraph devoted entirely to numbers, then executive summary organized as highlight sentences followed by explanatory numbers. To this reader, all this text seems highly (carefully?) technical, backed by best numbers. If so, then I do not understand purpose for exec summary. If authors want exec summary included in a reviewed document, they should eliminate as much redundancy as possible? Summary highlight sentences should go in conclusions? Or into abstract, in place of quantitative paragraph? Or, they could make exec summary as a separate document, used on GCP website? In present formats, I do not understand purpose of exec summary.

We felt, in agreement with the ESSD editors, that an executive summary was appropriate given the length and amount of information in the main text. We tried to improve the language in the executive summary to make it less technical.

2) Page 5 Lines 15, 16 - “patterns reflect the stringency of the COVID-19 confinement levels”: Which patterns? 5% drop in 2020? 5% rebound in 2021. Combined drop-then-rebound pattern? Country-to-country comparisons? Authors raise confusion with this statement.

Thank you. We rephrased to clarify: These changes in 2021 emissions patterns reflect the stringency of the COVID-19 confinement levels in 2020 and the pre-covid background trends in emissions in these countries.

3) Page 5 Lines 17 to 19 - 23 countries achieved significant reduced emissions over past decade but these countries do not represent the big emitters? But sources remain national reports which can be ‘cooked’ according to country preference? Here the authors seem to intend to write for a non-expert reader but they somewhat fail to make their point?

Indeed, as we wrote, "these 23 countries contribute to only about one quarter of world CO2 fossil emissions". Not clear what the rest of the comment is exactly about, our point is quite simple and seem clear: .

4) Page 5 lines 20 to 30 - more confusion here? All LULUC refers to managed land? Emissions only changed due to changes in management? Decrease (significant?, not significant?) over prior decades not well documented here?

These are global CO2 emissions from land-use, land-use change, and forestry as written in the headline sentence. This refers indeed to managed land (i.e. land used). The decrease is over the past two decades (2000-2019) as written in the headline sentence.

5) Page 5 line 29 - "the (rising) importance of degradation": Degradation here means land previously used as cropland or grazing land now abandoned? Or, burned? Not clear what the authors intend here?

Forest degradation here refers to the partial loss of forest function and structural integrity from disturbance, but does not result in a change of land cover

6) Page 6 lines 6 to 10: important statement, has gotten or will get much attention, but seems somewhat of a diversion for GCB? Also, line 13 refers to "net zero". Do authors adopt political conventions of assuming unproven unrealistic CO2 removals, or do they mean quantitatively-rigorous zero emissions? Need more careful language here, to avoid misinterpretations?

We follow the same approach as in IPCC AR6 WG1. What we present here is the remaining carbon budget to keep warming below 1.5, 1.7 or 2°C. It is update from IPCC as IPCC AR6 estimated the budget since 2019. Here we account for the emissions that occurred in 2020 and 2021, hence reducing the remaining carbon budget. To avoid confusion and policy interpretation, we changed "net-zero" by "zero" in this statement as this estimate does not make any assumption on carbon dioxide removal.

7) Page 6 line 21; global reduction of 0.18 ppm? Really? Hard to find any evidence for such reduction on e.g. CO2 Earth (NOAA)? Ironically, 0.18 change here equals exactly the calibration change (likewise 0.18 ppm) outlined on page 16. Circumstance?

There is a misunderstanding here. We don't say atmospheric CO_2 went down by 0.18ppm, we only said that the reduction in emissions of 0.7 GtC in 2020 implies a reduction in the CO_2 growth rate of about 0.18 ppm. However, we decided to remove this sentence as potentially confusing and not critical that paragraph.

8) Page 6 lines 22 to 29: A statement about real change in ocean uptake or about current deficiencies in ocean observations? Both? Can one conclude the former while acknowledging the latter?

These lines describe consistent changes across methods ('resumed a more rapid growth') and discrepancies between methods. Discrepancies between methods are clearly reported ('the growth of the ocean CO2 sink in the past decade has an uncertainty of a factor of three, with estimates based on data products and estimates based on models showing an ocean sink increase of 0.9 GtC yr-1 and 0.3 GtC yr-1 since 2010, respectively'). This source of discrepancy (model bias or lack of observations or other methodological issue) cannot be clearly identified. We refer the reader to the main text for more information.

9) Page 7 lines 5 to 7: Important statement here but redundant with text above?

Sorry, we don't see where this text is redundant with previous text.

At this point, before conventional Introduction, reader has encountered exec summary containing / highlighting seven important points. Authors have conveyed mixed message. If abstract and introduction, followed by methods, results, and discussion/conclusion, proceed in well-written

sequence as expected for ESSD product, with exec summary added to provide a short-cut for readers who do not want, or lack time, to read entire manuscript, good. But language of exec summary remains too similar to normal technical text, so that it does not appear friendly to non-experts? In attempting to extract, authors have too many times added confusion. Get someone else, outside of this group, to write an exec summary? Make it a separate product from this complete description manuscript? I think I understand intent, and I applaud effort for this product, but outcome not as clear or distinct as authors might have liked. Making it a separate product would save approx 3 pages here?

See earlier comment. We felt, in agreement with the ESSD editors that an executive summary was appropriate, given the length and amount of information in the main text. We tried to improve to the language in the executive summary to make it less technical.

Page 8 line 4: reader sees 412 ppm here but just a few lines (page 6 line 17) earlier saw 414.7, almost 415 ppm. Need to make clearer distinction between final QC'd value for 2020 (here) and first projections (earlier)?

Indeed, as described in the text, the numbers here are the observed atmospheric CO2 data for 2020 while the numbers in the executive summary are the projection for 2021.

Page 8 line 25, 26 - "to quantify the permissible emissions for a given climate stabilization target": But, 'permissible' emissions involve a morass of social assumptions and choices, as evidenced by massive literature around SSPs. Can this group really quantify future emissions as a function of a biogeochemical carbon cycle separate from vague social choices? I understand desire to see this product take a greater impact on social change but I worry slightly that authors 'bend' their otherwise-excellent quantitatively-rigorous product toward highly-uncertain future estimates.

There is a misunderstanding here. We are only saying that an understanding of the global carbon budget is necessary to quantify the link between emissions and climate target. Every climate target is associated with a given amount of CO_2 emission (that is the remaining carbon budget). Improving our understanding on the carbon cycle can only help quantifying this remaining carbon budget. We slightly revised the sentence to make it clearer.

Page 13 line 15 - "all other countries combined"- a bit vague, somewhat awkward, allows reader confusion?

Not sure why this is awkward/confusing. We literally mean to say: all other countries, aggregated as one group.

Page 16 lines 16, 17: these represent impacts of calibration corrections, not actual emissions reductions! Authors know exactly what they intend but they here open the door slightly to reader misinterpretation.

Indeed. Clarified now.

Page 17 line 9 - "0.17 GtC yr-1 for 1980-2020": This number is essentially identical to the decrease authors have reported due to Covid-19?

This is pure coincidence.

Page 23 line 10: same 30+ aircraft CO2 measurement projects as listed in prior verions? If so (I have only done a perfunctory comparison), these could be cited rather than re-reported? Save another formatted page or two?

Thank you for the suggestion. This information does indeed include only minor updates from version to version and we could save space by backward citing and listing only updates. However, we feel that if we only list the updates per year/release it would become nearly impossible to piece together the full suite of datasets used per GCP release. It would require the reader to access previous versions as well as the current one to get the information complete. We therefore prefer to keep the table complete as is, at the expense of 1,5 pages of formatted space as indicated by the reviewer.

Page 24 line 10, Fossil fuel emissions: In all these results sections, authors report based on historical (1850-2020), recent (1960-2020), final (2020) and projection (2021). Not until partitioning discussion at section 3.7 (top of page 40) does reader again encounter decadal results. But, at least through exec summary and introduction, authors have presented decadal outcomes and trends as of primary interest. Reader needs to know beforehand that decadal trends relate only (primarily) to component exchanges and regional or country-specific assessments?

We do provide decadal information in the sections about the recent period 1960-2020 (sections 3.1.2, 3.4.2, 3.5.2, 3.6.2). In these sections, we give the decadal values for the first (1960s) and last (2010s) decades and we also refer to Table 6 that gives data for each individual decade. The 2010s decadal estimate is provided in each component section, the only exception was for the land use emission 3.2.2 where we omitted to give it. This has been corrected now.

Page 43 line 23: extra or misplaced comma here?

Done

Page 44 line 16: FACE experiments?

Defined now

BIM discussion starting from page 45 line 22 = excellent!

Thank you

Page 47 line 24 'Tracking progress': Again a small voice of caution. After pages, table and charts of highest quality with itemized uncertainties and extensive validation, authors next turn to a purely political agreement from Paris. If the information here seems or proves relevant to that agreement, good. But readers can get the sense that Paris agreement contains hard QC'd targets, which it emphatically does not. Authors use their hard (and, hard-won) numbers to show progress toward a soft target?

Misunderstanding. This section is not a "purely political agreement from Paris". The information we provide here are: 1) an brief analysis of the countries where emissions have been declining over the last decade; 2) a Kaya analysis of drivers of growth/decline in emissions for the major economies (Fig 14) and 3) an update of the IPCC AR6 estimate remaining carbon budget consistent with climate targets. These are factual analysis, nothing "purely political".

All these discussion rely entirely on national reports which - unfortunately - we must regard as estimates at best or as manipulated at worst. Uncertainty discussion (e.g on page 50) focuses on sectors, definition boundaries, activity factors etc. but seems nowhere to acknowledge deliberate mis-reporting? Here, however, authors take readers through a logical, orderly, quantitative assessment (e.g. through pages 48, 49 etc.) Meanwhile, as reported earlier in manuscript and as reported hourly, daily, monthly, annually etc. by NOAA, atmospheric CO2 concentrations rise consistently and relentlessly. Nothing I write will seem unfamiliar to these authors, but their products seems to divide here: the reality of atmospheric concentrations on the one hand vs these hopeful projections about remaining emissions on the other. Annual GCB must acknowledge and report latest data relevant to both views, but in a way that leaves readers/users clear about what represents hard data and what represents political and politically-motivated targets? I don't know what to suggest as clear separation or resolution but present format seems to give equal credence to both aspects. Perhaps make clearer somehow (as in your uncertainty sections) where you rely on measured concentrations and where on national reports? If national reports referenced to actual concentrations? Great! But national reports with the same apparent credibility as measurements? Cautious.

Not sure how to respond to this long comment with several unrelated threads. 1) Reporting of fossil fuel emissions is the best we have. They could be subject to mis-reporting manipulation but that's virtually impossible to assess. We note that such misreporting would ned to be consistent in time as we do not see any suspicious change in annual estimates from individual countries.2) We don't understand the second comment about "our products seeming to divide" atmospheric CO_2 concentration is going up because of continuous anthropogenic CO_2 emissions, hence the remaining carbon budget is reducing. We do not see where in the manuscript we would have written anything about "hopeful projections ". Likewise, we don't understand what the reviewer means by "data relevant to both views". We don't know what these both views are supposed to be and why the reviewer refers to politically mitigated targets. 3) the last comments seem to confuse emissions and concentrations. Fossil fuel emissions are relying on country level reports, global atmospheric concentrations are directly inferred from measurements from the NOOA/ESRL network. This is clearly described in section 2.

Page 49, lines 15 to 17: Confused again. a) Net zero here means quantitive zero net emissions, not politically expedient net zero based on future imagined reductions? b) If apparent 0.5 GtC reductions due to Covid-19 in 2020 were NOT matched by equivalent reductions in atmospheric CO2, then how can we advocate similar or continued emissions reductions of that magnitude? I do not dispute goals or policy, but data shown here suggest that 2020 Efos changes had minor to zero quantifiable impact on global atmospheric CO2?

Again, the reviewer seems to be confusing emissions and concentrations and/or concentration and concentration growth. Fossil fuel emissions declined by 0.5GtC (5%) due to the COVID-19 pandemic. Given than the world still emitted more than 10GtC in 2020, atmospheric concentration kept increasing. As we wrote, such reduction should be sustained every year until we reach zero emissions in order to stop atmospheric CO2 increase. One single year is not enough.

Page 51 line 8 - NGHGI?: One suspects 'National GreenHouse Gas Inventories' but the acronym needs accurate definition.

Already defined in section 2.2.

For the most part, consider this list of comments as suggestions only. One reader encountering this product from a personal viewpoint. A few typos you will want to fix but otherwise not much that requires definite change.

Thank you.