

Reply to comment of Anonymous Review #2.

Reviewer comments are displayed in italics, our responses in roman font.

Reviewer comment:

General comments

To introduce the OAE best practices guide, this chapter provides the background, motivation and aims of this document, whilst impressing the relevance and timeliness of advancing CDR science, and the role OAE can play. The chapter is well-written and includes references that appropriately situate this text within the conversation of relevant scientific literature.

Section 1 does a good job of providing the salient information for the reader to understand the importance and need of CDR in climate action portfolios to achieve the Paris Agreement goals. However, at times I felt the flow of the arguments and the structure of the paragraphs could be improved for increased clarity, and have made a few suggestions in the “Technical comments” section of my review.

Section 2 establishes the need for ‘novel’ approaches outside of land-based CDR (i.e. the role the ocean can play) in order to reach net-zero. Importantly, the authors highlight the pressing need to address knowledge gaps in efficacy, risks and benefits, as well as intersecting societal factors. Crucially, the authors make the case for the urgent need for research now, in order to make well-informed decisions in future. At the end of this section, the concept of MRV is introduced. Since this text forms an introduction, and considering the nature of this guide, a short paragraph explaining MRV, its role and general current challenges could be useful here.

Section 3 provides a clear summary of OAE – how it works, where it can be applied and where research on OAE currently sits. Addressing these knowledge gaps provides the motivation for the guide presented in Section 4, which provides an overview of the contents. Section 5 situates the this guide within the context of similar initiatives as well as outlines the project development, protocol for transparency and stakeholder involvement. Overall, I congratulate the authors on this chapter. Minor specific and technical comments can be found in the attached pdf file.

We thank reviewer #2 for the supportive evaluation and very helpful and constructive comments! All recommendations and suggestions in the ‘Specific comments’ and ‘Technical comments’ are much appreciated and addressed individually below. A short paragraph explaining MRV, its role and general current challenges will be included in section 2 as follows:

‘A particular challenge for marine CDR concerns monitoring and verification of any CDR-induced carbon fluxes and carbon storage, essential for appropriate carbon crediting. Detection and attribution of OAE signals is particularly challenging due to the large natural marine carbon pool that already contain a considerable anthropogenic perturbation, their high resolution temporal and spatial variability and the spatial and temporal decoupling of air-sea CO₂ fluxes and carbon storage in the interior. The determination of a baseline, of the additional carbon sequestered, and of its durability will likely be associated with considerable uncertainties. A key aspect of Monitoring, Reporting and Verification (MRV) is the development of transparent schemes that allow a reliable determination of OAE itself, and of

consequent impacts on the carbon cycle and hence climate, as well as the association of carbon credits with individual OAE activities.'

Specific comments

- *Lines 26-28. Quantifying this statement would strengthen it. Why are ambitious reductions required? How close are we already to reaching these thresholds?*

We will add that 'Achieving the Paris Agreement...can thus be converted to a remaining carbon budget that, for current global emissions, will be used up in a few years for the 1.5°C target and about 2 decades for the 2°C target (United Nations Environmental Programme, 2022).

- *Lines 29-32. The last sentence of this paragraph feels a bit out of place as it is retrospectively explaining the statement in the first sentence in this paragraph of why GHG reductions are needed. I suggest moving the last sentence to the beginning of the paragraph. If you end the paragraph on the idea suggested in the previous bullet point, it will still tie nicely into the second paragraph.*

We agree and thank the reviewer for this suggestion and will change the sequence of sentences accordingly.

- *Line 40. Define "balance" – do you mean net zero? I think net zero is a more precise term so I would recommend using that instead of balance when possible*

The term 'balancing' was introduced by the Paris Agreement and we therefore want to keep it. We will add 'i.e. net zero' after 'achieve a balance'.

- *Lines 139-140. "Attractive aspects of OAE compared to many other methods, in particular those that store carbon in biomass, are its potential to reduce ocean acidification at least locally" – can the citation Albright et al 2016 (10.1038/nature17155) be used here? I see it is mentioned later in line 162 but think it could be useful here as well.*

Thanks, good point. The reference will be added here.

- *Lines 153-167. This is a minor suggestion. In this paragraph, two types of studies are presented as providing evidence on the effectiveness and impacts of OAE: modelling and experimental studies. While the benefits and limitations of each approach, and how they complement each other, is alluded to in the text, I think these key points could be clarified – i.e. that modelling studies while simplifications of reality can provide large-scale estimates of CDR potential, while small-scale experimental studies give insight into realised effectiveness of alkalinity additions and measuring impacts that cannot be predicted from simplified modelled systems. However crucial knowledge gaps in determining the best method for alkalinity deployment, the optimal alkaline materials to use, etc. limit our ability to accurately predict the carbon storage potential and co-benefits/risks of OAE. This suggested re-organization might*

transition better into section 4.

We follow this helpful suggestion to improve the clarity and structure of the manuscript and will amend the section accordingly.

Technical corrections

We thank the reviewer for these detailed and helpful corrections!

- *Line 19. ... and marine CDR options are receiving more and more interest*

done

- *Line 26. Achieving the Paris Agreement's goal of limiting global warming to well below 2°C above pre-industrial levels*

done

- *Line 43. I think this sentence can be interpreted in a way that contradicts a bit with the sentence previous, because not "all" greenhouse gas emissions need to be avoided (i.e. complete stop of any emissions whatsoever). Recommend phrasing such as: "Since it is not foreseeable that this can be achieved through reducing GHG emissions alone, ..."*

done

- *Line 46. I was a bit confused as to why the narrative transitioned from talking about CO2 removal to non-CO2 greenhouse gas removal. I had to read this sentence several times to understand it. For more easy reading, I suggest starting with something like: "Even in scenarios with very aggressive CO2 emissions reduction, it is likely CDR will still be necessary to compensate for the emissions of industries that are difficult to de-carbonize (e.g. cement production, etc), or for non-CO2 greenhouse gas for which no viable large-scale removal technologies presently exist." I was also going to recommend adding a citation here, but then all the support from literature appears in the next paragraph. Consider even cutting this paragraph at "Since it is not foreseeable ..." and then joining this with the following paragraph.*

We have re-arranged this sentence as follows:

'Therefore, carbon dioxide removal (CDR) will likely have to balance not only hard-to-abate residual emissions of CO₂, e.g. from cement production, waste incineration, aviation and maritime transport, but also those of non-CO₂ GHGs, in particular from agriculture.'

- *Line 61. First 2 sentences here read almost as a concluding/summary sentence for previous paragraph*

Good point, we moved these 2 sentences to the previous paragraph.

- *Line 87. The way this is worded makes it seem like all EBS are terrestrial. Perhaps clarify as “land-based EBS”? Because I do not think it is intended to include coastal blue carbon EBS also in this category*

Yes, thanks, good point. Added ‘terrestrial ecosystem-based solutions’.

- *Line 112. To transition to the next section, and declare the focus of the document, perhaps provide a concluding sentence about how here you choose to focus on a particular abiotic method, OAE, because [...]*

Thanks for this suggestion to improve the text. We now refer to the assessment provided by the report of the National Academies (NASEM, 2021) and add: ‘Among marine CDR methods investigated, abiotic approaches have been assessed as those with the lowest knowledge base and highest efficacy (NASEM, 2021). Improving their knowledge base therefore appears prudent, and we here concentrate on ocean alkalinity enhancement.’

- *Line 207. Since the amount is reported in US dollars, I recommend using the US convention of 170,000 rather than 170.000*

done

- *Lines 339-343 (Figure 1 caption). I think the text in the figure caption does not appear to accurately match the figure. For example “dark green” is referenced but I do not see dark green anywhere on the figure. Please check.*

Uups, sorry and thanks for pointing this out. We had switched figure formats from an earlier version back to the original IPCC color scale without adapting the figure caption. Now corrected.