This article looks at the Earth system impacts of measures referred to as ‘climate adaptation’. These measures include modifying the flow of water, building and maintaining residential structures, and refrigeration. They discuss general findings of the literature and provide approximate estimates for the CO2e emissions associated with the measures.

I feel this is a useful article that makes some valuable points. However I think it needs major revision prior to publication. This revision should clarify the language, to prevent dangerous misinterpretation, and should also restructure the text to reduce repetition and focus the message.

Most importantly, the authors need to take greater care in distinguishing between 1. the adaptation to local climate for any reason, and 2. adapting to climate change. The latter is what is typically meant by ‘climate adaptation’, yet the authors are inconsistent in their use of the term, sometimes applying it to one and sometimes the other. For the purposes of this article I might suggest they differentiate ‘local climate adaptation’ vs. ‘climate-change adaptation’, where the second is a component of the first.

Once the authors have decided how to deal with this, the abstract needs to be significantly rewritten, to first introduce the reader to the idea of what is meant by adapting to the local climate, so that the meaning of the ’26%’ of emissions and ’74%’ of freshwater are clear. Otherwise the reader will assume that these amounts are for adaptation to climate change, which would be incorrect. Many parts of the manuscript will need to be adjusted to be consistent with this (too numerous to list here).

We would like to sincerely thank the reviewer for those highly constructive and helpful comments, which help us improve critical areas of our paper.

Specifically regarding the framing, we have had many internal discussions about the best solution for this concern.

One the one hand, an Earth system-based perspective is required here and one needs to ensure that all Earth system effects of climate adaptation are considered in the attribution analysis. That is to say, for attributing the current pressure of climate adaptation on the respective Planetary Boundaries the primary focus has to be on the influence of *all* forms of climate adaptation. Whether that adaptation is due to climate change or would also have occurred due to e.g., economic or population growth is the secondary question. Therefore, one overarching term is needed under which both a) adaptation to Holocene-like climate and b) anthropogenic climate change can be subsumed. As cited in the paper, the decision was taken to work with the official IPCC definition, which explicitly frames “climate adaptation” as a process of adjustment to both actual *and* expected climate (IPCC, 2022, p.5). On the other hand, we also acknowledge that many researchers and policymakers understand and frame “climate adaptation” almost exclusively in terms of adaptation to anthropogenic climate change, which could lead to misinterpretation that the reviewer is rightly concerned about.

In order to avoid any confusion, we use the term *climate adaptation* in line with IPCC language as encompassing all adaptations regardless of whether in response to or anticipation of current or future climate. In contrast to this, the term *climate change adaptation* is explicitly used when that adaptation would not have been necessary without climate change. In the revised version, we have taken extra care in clarifying this distinction both in the main text and in the abstract in order to avoid any misinterpretation.

The manuscript could also be greatly improved by reducing repetition (especially in section 1) and focusing on the novel findings.

Given the relatively new Earth system-based perspective on climate adaptation taken in this paper, we considered it necessary to recapitulate some important concepts before diving deeper into the actual analysis. However, we also acknowledge that a stronger focus on the novel findings could improve the paper. Substantial parts of section 1 and the introduction were therefore rewritten in the revised version in order to reduce unnecessary repetitions and focus more strongly on the novel findings.

Specific comments:

- I didn't find the four functional mechanisms (line 120) very intuitive. It was hard for me to understand why the first two would be called 'flow' and "boundary', given what is meant by them. Also, I wondered why is a green wall would be functionally different than a cement wall? However perhaps these are better explained in the cited paper (Ott et al., 2025 submitted)?

Right, indeed the cited paper explains these mechanisms in much more detail and we would be pleased if we could provide the reviewer with a copy of the paper. In the process of rewriting substantial parts of section 1 (see comment above), further clarifications were also added on this point here. Regarding the distinction between flow, boundary, and organic climate adaptation, please see an excerpt from the cited paper here:

"Some forms of climate adaptation involve self-sustaining systems (e.g., human bodies or social-ecological systems such as mangroves in inhabited coastal intertidal ecosystems, forests within cities etc.), which organically regulate a specific climate through their own anatomy and metabolism (e.g., cooling through (evapo-)transpiration). Such organic adaptations can occur at different scales and hence also comprise e.g., genetic adaptations (Catullo et al., 2019). […] Others forms of climate adaptation redirect existing flows of energy or matter generated by other self-sustaining systems (e.g., atmosphere, rivers, oceans) through artificial spatial boundaries (e.g., seawalls, jetties, floating roads, water reservoirs). This will be called boundary climate adaptation. Lastly, some forms of climate adaptation externally initiate new continuous flows of energy or matter in order to maintain a specific climate (e.g., A/C, water desalination). This is termed flow climate adaptation. It is crucial to distinguish functionally whether artificial climate niches are maintained organically, through behaviour, through boundaries or through flows. This is because depending on the corresponding socio-metabolic profile of these functional layer of adaptation, different Earth system interactions can be expected." (Ott et al., 2025, p.9 f.)

- calling all refrigeration 'climate adaptation' seems like a stretch, since much of it is to preserve food... is it true that's what being done here?

Right, it would indeed be more precise to generally talk about “artificial cooling” here instead of “refrigeration” in order to avoid any confusion (in the sense that cooling comprises A/C etc. but also refrigeration). In all applicable cases “refrigeration” was changed to “artificial cooling” in the text. However, we would also like to mention that from an Earth system-based perspective, refrigeration indeed is an example of climate adaptation as it constitutes a spatially-confined niche in which surface (air) temperature is significantly, temporarily and intentionally modified by humans and for human benefit.

- Line 171 phrase starting ‘However, one should also account…’ was very hard to understand.

We would like to thank the reviewer for this concern, which we take seriously. In the revised version, we rewrote this paragraph in order to make the interactions between Planetary Boundaries clearer to understand.

- The disagreement with Abajian et al., 2025 seems important - I’d request more detail regarding this comparison. Is it true that they only included CO2? What specifically is wrong with their analysis?

Yes, sure, in fact Abajian et al., (2025, p.8) even explicitly acknowledge this limitation: “the absence of non-CO_2 GHG emissions intensities prevent us from directly quantifying corresponding changes in non-CO_2 emissions due to adaptation.” In our mind, this is indeed a critical limitation given that a substantial part of cooling-related GHG emissions actually consist of non-CO_2 GHG emissions (primarily refrigerant emissions). According to UNEP (2025, p.29), 36 percent of 2022 global cooling-related GHG emissions came from non-CO_2 GHGs (refrigerants). Depending on future cooling scenarios and the success of the Montreal protocol and the Kigali amendment, this share could range from 5 percent to 59 percent by 2050 (ibid.,). Moreover, the non-CO_2 effects of artificial cooling are complex given that different refrigerants have different atmospheric residence times and are released over different time scales (Daniel et al., 2007; Lickley et al., 2020; Velders et al., 2007, 2022). If an important part of the GHG emissions linked to artificial cooling is disregarded by study design, the balance between future reduced heating-related emissions and future increased cooling-related emissions can change substantially. In contrast to Abajian et al., we have not conducted process-detailed modelling of future emissions as our focus was on current emissions. Yet our analysis which generally includes all GHGs and not just CO_2 calls the results of Abajian et al., into question. We have further sharpened this argument in the revised version.

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