Thank you for inviting me to review the paper "Respecting the boundaries – balancing climate adaptation and Earth system resilience" by Ott et al. Sometimes, when you come across an idea, it seems such an obvious point, yet to my mind there is relatively little existing research on what this paper addresses. Basically, what additional future emissions will arise from adapting to climate change? We have all heard the ironic points made, for instance, that as the planet warms, people will buy AC units, which use fossil fuels to run. And so amplify the problem. Here, the authors quantify this positive feedback, estimating its magnitude at around 25%. An interesting parallel calculation shows that this rises to around 70% for freshwater use (e.g. increased crop irrigation in a warming world).

I like the paper, but the version reviewed here feels slightly rushed. Here are a few suggestions if the authors would like to prepare a new version, which may help towards a high-standard paper suitable for ESD.

We would like to sincerely thank the reviewer for these critical and constructive points, which help us further improve the paper in order to fully meet the high standards of ESD. Please see a point-by-point response below.

Kind regards,
Bastian Ott, Jonathan Donges, and Johan Rockström

- On the definition of adaptation feedbacks, make this very clear – it is the additional energy consumption likely to be associated with adapting to a new climate. It is not that we plan for a specific emissions scenario (i.e. a high-mitigation one) but then find we cannot adapt fast enough – so we burn extra emissions.

Yes, good point, this is going to be further highlighted in the revised version as this is indeed a critical distinction.

- The reason for (1) above is that the title is slightly misleading. I was expecting to see a "U"-shaped graph, perhaps of cost to society (y-axis) against emissions reductions (x-axis). On the left-hand side of the plot, emissions would be reduced so quickly that it would be prohibitively expensive. On the right-hand side, we choose not to reduce emissions so quickly, but there are major impact costs from a changing climate, despite attempts to adapt to climatic change.

If we understand the reviewer correctly, the reviewer alludes to the seminal question of balancing the costs of mitigation and adaptation with the costs of climate change (finding an "optimal" mix of mitigation and adaptation). This question has certainly been discussed in the literature for quite some time (e.g., Nordhaus, 1991; Stern, 2007). However, here we would like to introduce the reader to another important question: given a specific level of climate change (SSP/RCP) – can the implied level of necessary adaptation be reconciled with safeguarding the Planetary Boundaries? That is, there is not only a need to balance the costs of adaptation and mitigation (economic dimension) but also to balance the need for adaptation with the limitations of the Planetary Boundaries (biogeophysical dimension). As many readers might have similar concerns and probably are also familiar with the economic discussion, we are going to address this distinction explicitly and shortly in the revised manuscript.

- Do the 25% and 70% figures depend on the emission scenario – i.e. the SSPs? And on the future time?

Yes, in fact the 25% and 70% figures describe the *current* pressure of climate adaptation on these proxies for the Planetary Boundaries (GHG emissions and freshwater withdrawals, respectively). As climate change will increase the need for adaptation, the pressure on the respective Planetary Boundaries in the respective SSPs is likely to be even higher than today. We are going to highlight this result in the paper more strongly in order to avoid any possible misinterpretation regarding the temporal dimension of the analysis.

- Do the standard SSPs partition emissions so that the "extra bit" causing adaptation is identified by scenario and future time (e.g. the standard Meinhausen papers)? Although the authors make good use of the literature, I did at times struggle to understand how the analysis fits within the context of existing work.

As discussed in the introduction, there are substantial gaps in scientific understanding when it comes to quantifying the "extra bit" of e.g., GHG emissions related to adaptation to climate change. Moreover, there are even challenges in identifying the current contribution of the current level of adaptation to climate to current annual GHG emissions. We have written about this in more depth in Ott et al., (2025, p.2): "Human climate adaptation, like many other relevant human dynamics, is usually not systematically and realistically represented in Earth system models (Beckage et al., 2018, 2020; Donges et al., 2020). The first integrated assessment models (IAMs) which did consider climate adaptation only included assumptions about a global level of adaptation implicitly as part of damage functions; later, adaptation was included more explicitly e.g., via scenario or control variables (Füssel, 2010; Patt et al., 2010). In the scenario database of models used in the latest Intergovernmental Panel on Climate Change (IPCC) WG2 assessment, variables linked to adaptation such as irrigation, cooling, afforestation and reforestation, and building retrofits can be identified (AR6 Scenarios Database hosted by IIASA, 2026). Moreover, the most recent iteration of the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP) focuses specifically on future impacts and adaptation; simulation experiments consider different human forcings including e.g., land-use and irrigation, reservoirs and dams, and seawater desalination (ISIMIP3 simulation protocol, 2026). Yet a realistic, spatially-explicit, process-detailed, dynamic implementation of all relevant forms of adaptation in IAMs as well as in most climate impact models (CIMs) has still remained largely elusive (Andrijevic et al., 2023; Colelli and Cian, 2020; Holman et al., 2019; Van Maanen et al., 2023). Importantly, even the models which do consider adaptation explicitly apparently do not represent climate adaptation-Earth system-feedbacks accurately (Colelli and Cian, 2020)."

Some of these sources have been added to the revised version in order to further add context from the literature.

- The authors have published extensively on climate boundaries ("guardrails") over the years, and the paper, including the title, suggests that readers can expect much on this here. But there is no diagram or plot where this jumps out. Is there a way to create a figure that relates back to the influential figures in the authors' earlier papers?

We can very much relate to this idea and have discussed this internally multiple times. As proxies for the "official" control variables of the Planetary Boundaries are used in this study here, we consciously decided to not use the standard Planetary Boundaries figure here in order to avoid any potential for misinterpretation. In the discussion section, we have discussed which additional (compute-intensive) steps would be necessary to link climate adaptation explicitly to the "official" control variables of the Planetary Boundaries.

- Please include a couple of specific examples in the Abstract. This always helps the general reader. For emissions, state the example of increased energy use with AC units, and for freshwater, state the example of increased water use for irrigation.

Yes, good point, specific examples for the analysed feedbacks are going to be included in the abstract in the revised version.

- Then, with the two examples in the Abstract, the reader can refer to the key Table 1 for other examples. I really like Table 1, and this should be the main focus of the paper, in my opinion.

Thank you, very helpful. We are going to further highlight the importance of Table 1 in the revised version.

- Some of the diagrams appear slightly rushed, not at publication quality, and are also slightly amateurish. Figure 3 might have been better as a histogram, with the left part as a two-bar histogram and the right part as a single bar with subdivision (as shown already).

We would like to thank the reviewer for this feedback, which we receive constructively. All figures were redesigned in order to address these concerns (see also the specific suggestion for Fig. 4 below).

- Figure 4 has far too many vertical tick marks, an excessively small legend, and unnecessary vertical and horizontal lines.

Figure 4 was redesigned in order to address these concerns. The number of vertical and horizontal tick marks and lines were reduced to a necessary minimum and all font sizes were increased (especially for the legend). Further, the title above the diagram was removed and the title of the vertical axis was changed accordingly. Lastly, for further simplification, the percentages on the vertical axis are now displayed without decimal points and the caption was slightly amended.

- Some of the previous work on planetary boundaries is cited and referenced, especially in the Conclusions. I found some of the terms used (e.g. "niches") to be quite specific to the boundaries approach. A clearer explanation of the terms used would be helpful. Indeed, as the paper is quite text-based, it might help to include a table of key terms or words used, and their explanations.

Yes, a list of key definitions is going to be added to the text in order to clarify the respective terms.

- This is an important paper, but it feels rushed. I am very happy to review any revised manuscript. With care and attention, I believe it could make a valuable contribution to ESD.

Literature

Andrijevic, M., Schleussner, C.-F., Crespo Cuaresma, J., Lissner, T., Muttarak, R., Riahi, K., Theokritoff, E., Thomas, A., Van Maanen, N., and Byers, E.: Towards scenario representation of adaptive capacity for global climate change assessments, Nat. Clim. Change, 13, 778–787, https://doi.org/10.1038/s41558-023-01725-1, 2023.

Beckage, B., Gross, L. J., Lacasse, K., Carr, E., Metcalf, S. S., Winter, J. M., Howe, P. D., Fefferman, N., Franck, T., Zia, A., Kinzig, A., and Hoffman, F. M.: Linking models of human behaviour and climate alters projected climate change, Nat. Clim. Change, 8, 79–84, https://doi.org/10.1038/s41558-017-0031-7, 2018.

Beckage, B., Lacasse, K., Winter, J. M., Gross, L. J., Fefferman, N., Hoffman, F. M., Metcalf, S. S., Franck, T., Carr, E., Zia, A., and Kinzig, A.: The Earth has humans, so why don't our climate models?, Clim. Change, 163, 181–188, https://doi.org/10.1007/s10584-020-02897-x, 2020.

Colelli, F. P. and Cian, E. D.: Cooling demand in integrated assessment models: a methodological review, Environ. Res. Lett., 15, 113005, https://doi.org/10.1088/1748-9326/abb90a, 2020.

Donges, J. F., Heitzig, J., Barfuss, W., Kassel, J. A., Kittel, T., Kolb, J. J., Kolster, T., Müller-Hansen, F., Otto, I. M., Wiedermann, M., Zimmerer, K. B., and Lucht, W.: Earth system modelling with complex dynamic human societies: the copan:CORE World-Earth modeling framework, Earth Syst. Dyn., 11, 395–413, https://doi.org/10.5194/esd-2017-126, 2020.

Füssel, H.: Modeling impacts and adaptation in global IAMs, WIREs Clim. Change, 1, 288–303, https://doi.org/10.1002/wcc.40, 2010.

Holman, I. P., Brown, C., Carter, T. R., Harrison, P. A., and Rounsevell, M.: Improving the representation of adaptation in climate change impact models, Reg. Environ. Change, 19, 711–721, https://doi.org/10.1007/s10113-018-1328-4, 2019.

AR6 Scenarios Database hosted by IIASA: https://doi.org/10.5281/zenodo.5886911

ISIMIP3 simulation protocol: https://protocol.isimip.org/#/ISIMIP3b/, last access: 24 February 2026.

Nordhaus, W. D.: To Slow or Not to Slow: The Economics of The Greenhouse Effect, Econ. J., 101, 920–937, https://doi.org/10.2307/2233864, 1991.

Ott, B., Donges, J. F., and Rockström, J.: Climate Adaptation in the Anthropocene: Towards an Earth System-Based Perspective, Rev., 2025.

Patt, A. G., Van Vuuren, D. P., Berkhout, F., Aaheim, A., Hof, A. F., Isaac, M., and Mechler, R.: Adaptation in integrated assessment modeling: where do we stand?, Clim. Change, 99, 383–402, https://doi.org/10.1007/s10584-009-9687-y, 2010.

Stern, N.: The Economics of Climate Change: The Stern Review, Cambridge University Press, Cambridge, 2007.

Van Maanen, N., Lissner, T., Harmsen, M., Piontek, F., Andrijevic, M., and Van Vuuren, D. P.: Representation of adaptation in quantitative climate assessments, Nat. Clim. Change, 13, 309–311, https://doi.org/10.1038/s41558-023-01644-1, 2023.