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To cite this article: Jan Wilkens *et al* 2025 *Environ. Res. Lett.* **20** 071005

IOP Publishing Environ. Res. Lett. 20 (2025) 071005 https://doi.org/10.1088/1748-9326/ade31e

ENVIRONMENTAL RESEARCH
LETTERS

OPEN ACCESS

RECEIVED
26 January 2025

REVISED
24 May 2025

ACCEPTED FOR PUBLICATION
10 June 2025

PUBLISHED
18 June 2025

PERSPECTIVE

Buying time or building futures? Conditions for sustainable climate change adaptation

Jan Wilkens[1,*], **Anita Engels**[1,2], **Eduardo Gonçalves Gresse**[1,2], **Andrés López-Rivera**[1], **Jochem Marotzke**[1,3], **Anna Pagnone**[1] and **Beate Ratter**[1,4,5]

[1] Center for Earth System Research and Sustainability, Universität Hamburg, Hamburg, Germany
[2] Department of Social Sciences, Universität Hamburg, Hamburg, Germany
[3] Max Planck Institute for Meteorology, Hamburg, Germany
[4] Department of Earth System Sciences, Universität Hamburg, Hamburg, Germany
[5] Helmholtz Zentrum Hereon, Geesthacht, Germany
[*] Author to whom any correspondence should be addressed.

E-mail: jan.wilkens@uni-hamburg.de

Keywords: climate change, climate futures, plausibility, sustainable adaptation

Adaptation to climate change seems an agreed-upon necessity in 2025. However, questions of how, by whom, and for what purposes this adaptation should be pursued remain far from obvious, especially if it is to be planned and implemented in a sustainable manner. In our most recent *Hamburg Climate Futures Outlook*, we conduct an assessment of the plausibility conditions for sustainable climate change adaptation across the world, and identify a number of missing elements (Engels *et al* 2024). In this *Perspective*, we summarize the findings of our assessment and discuss implications for climate action. We argue that three main issues are key to consider: first, it is essential to assess how climate change adaptation is understood in a given social context ranging from a reactive coping strategy to projected proactive engagement. Second, planning is a necessary but not sufficient condition for practicing and implementing climate change adaptation, and especially *sustainable* climate change adaptation. Third, to understand what makes climate change adaptation sustainable, research on and planning of adaptation require a better integration into the assessment of social dynamics of decarbonization and the physical context, such as internal climate variability and regional variation. To this end, we update our assessment of the social plausibility of achieving net-zero CO_2 emissions by 2050 (Engels *et al* 2023, 2024). Emissions through 2050 will directly influence the global warming trend in the coming decades, thereby shaping the context conditions for sustainable adaptation.

We further emphasize how internal variability and regional variation create additional challenges for adaptation planning in specific places. The central part of this contribution discusses facilitating conditions for sustainable climate change adaptation, drawing on lessons learned from nine case studies in different regions around the world.

In light of an increase in extreme events and resulting impacts on environmental and human systems (Seneviratne *et al* 2021, Puig 2022), there is new momentum around climate change adaptation, as demonstrated by the growing number of publications on adaptation and the rise in adaptation planning and implementation in recent years (UNEP 2024). Yet, although fundamental principles of the implementation of adaptation have been formulated (Rahman *et al* 2023), adaptation does not simply occur because it is deemed necessary. Furthermore, theoretical discussions about principles are not easily translated into specific, and at best sustainable, adaptation strategies. While transformative adaptation has been conceptualized as an ideal type within the academic debate in recent years, at COP29 in 2024 the African Group negotiator expressed discomfort during the negotiations on the global goal on adaptation, stating that 'we are not happy with the inclusion of transformation adaptation in the (negotiation) text as parties did not have adequate time to engage on the concept' (Mohamed 2024). This intervention may point to the dangers of using concepts, such as sustainability or transformation, if they are derogated to mere buzzwords. Scientists and policymakers alike need to address the meanings and potential implications of different kinds of climate change adaptation. What is the relation between sustainable and transformative adaptation? And what does meaningful societal participation look like in a period when

fatigue around transformation seems to dominate politics?

Assessing the conditions for sustainable climate change adaptation requires a more encompassing and, at the same time, context-specific approach. Research and planning must be better integrated with social dynamics of deep decarbonization and physical factors like internal climate variability and regional variation. Key aspects to focus on during this transformative phase include the integration of knowledge of interdependencies between mitigation and adaptation scenarios, while also elevating considerations of local contexts and socio-cultural dimensions in the design and execution of adaptation strategies. Since adaptation needs are highly local in nature, it is essential to assess a diversity of specific cases in order to evaluate the plausibility of sustainable climate change adaptation. Due to the social and physical specificities, there are no one-size-fits-all criteria to determine whether adaptation strategies and measures are sustainable or not. Against this background, the question is: under which conditions is sustainable climate change adaptation plausible?

While 'keeping 1.5 alive' remains a key focus of climate policy, recent research indicates that achieving the 1.5° target is not plausible under current conditions (Engels *et al* 2023, 2024). Despite efforts toward deep decarbonization by 2050, social dynamics, including shifts in consumption trends and corporate responses, hinder progress, complicating the pathway to a net-zero emissions society. Furthermore, the media ambivalence and ongoing fossil-fuel investments further undermine these ambitious climate goals (Engels *et al* 2024). Although the 1.5° target refers to the global scale, it shapes the conditions for climate change adaptation, considered to be regional and local endeavor (Gresse *et al* 2023, UNEP 2024), because global warming will affect regional physical boundary conditions in different ways.

Yet, the intricate link between social dynamics of deep decarbonization and signals of anthropogenic climate change are often further obscured by internal climate variability. The uncertainty arises from the complex and sometimes chaotic interactions within and between components of the climate system such as atmosphere, ocean, cryosphere, and land. Global warming exacerbates many extremes, but on the regional or local scale the distribution of internal climate variability is often wider than the anthropogenic effect. The interplay of regional variability and extremes poses particular challenges to the science supporting sustainable adaptation to climate change, for instance the capability of climate models to represent extremes, the attribution of extreme events to human influence, and the probability of compounding extreme events (Pagnone and Marotzke 2024).

For instance, in agricultural regions vulnerable to compound extreme events, adaptation measures are essential to mitigate threats to both local and global food security. Similarly, strategies addressing severe flooding and its consequent infrastructural damage highlight how vital it is to prepare adequately for costly and potentially life-threatening precipitation extremes. Marine heatwaves can catalyze ecosystem disruptions with consequences for the economy and for coastal protection, necessitating tailored community responses and a broad range of resilience-building initiatives (e.g. Smith *et al* 2021).

The perception of climate change adaptation as being distinct from climate mitigation is still a common misconception, failing to acknowledge the intricate relationship between the two concepts. Additionally, not all adaptation strategies and measures are sustainable. The overarching impact of social drivers on the success or failure of adaptation efforts hinges on the robustness of existing structural and institutional contexts, which currently exhibit minimal transformative change toward deep decarbonization. Climate change adaptation is already a necessity under contemporary conditions, and the importance of integrated climate action (combining mitigation and adaptation) will increase, given that deep decarbonization by 2050 is not plausible. Although many states are engaged in adaptation planning and discussions, current research underlines that reported adaptation measures are often not implemented (Berrang-Ford *et al* 2021, Petzold *et al* 2023, Reckien *et al* 2025).

We have developed a framework to assess diverse context conditions and the corresponding plausibility of climate futures by adopting and further developing existing concepts and guiding principles (Ratter *et al* 2024a). Based on the IPCC (2022) definition of climate change adaptation, we frame sustainable climate change adaptation as 'the process of adjusting to actual or expected climate change and its impacts by minimizing trade-offs and exploiting synergies between climate action and other sustainable development' (Gresse *et al* 2023, p 56, see also Ratter *et al* 2024a). Conceptually, adaptation responses can be classified into three analytical categories: (1) coping, (2) incremental, and (3) transformative adaptation (Fedele *et al* 2019). *Coping* strategies take the form of temporal, immediate, and reactive responses to climatic impact, not aiming at long-term systemic change. *Incremental* adaptation entails an echeloned approach along beaten paths, focusing on sector or context-specific adjustments, resulting in minor disturbances of systemic stability. *Transformative* adaptation encompasses broader and deeper actions directed at the root causes of vulnerabilities, encouraging fundamental changes in situations where incremental changes no longer suffice.

Methodologically, we have investigated the implementation of climate adaptation responses at the local scale using a descriptive, analytical, and interdisciplinary cross-site study comparing urban, rural,

and coastal areas with exemplary and diverse cases from all over the world. This was done against the background of the social plausibility assessment framework, which provides a conjecture informed by empirical evidence on past, present, and emerging dynamics and context-specific conditions affecting the realization of sustainable climate change adaptation (Jordan *et al* 2018, Aykut *et al* 2021, Engels *et al* 2024). Drawing on historical institutionalism and the critical junctures literature, the approach addresses the interplay of structure and agency as well as the role of both path dependency and the possibility of social change (Elias 1978, Hall and Taylor 1996, de Coninck *et al* 2018, Aykut *et al* 2021). Based on this approach and the context-specific nature of adaptation, our plausibility assessment framework of sustainable climate change adaptation centers enabling and constraining conditions (Cabana *et al* 2023, Wannewitz *et al* 2024). All case studies employ inductive reasoning and are grounded in qualitative data collected through a range of secondary sources, including expert elicitation, literature reviews, document analysis, systematized interviews, guided round table discussions, and on-site exploration of local and regional settings. To ensure consistency and comparability across the case studies, each author team was asked to complete an initial questionnaire that helped organize, systematize, and align their content. These interdisciplinary teams included experts from the respective regions who actively participated in conducting the comparative analysis. This collaborative approach was collectively prepared during two moderated workshops involving 25 organizing and co-authors, where the scope and conceptual procedures for the assessment were cooperatively developed, assessed by a steering group, and discussed among all participants. All empirical analyses, including data acquisition, were carried out between 2019 and 2023. This collaborative approach helped ensure content and empirical accuracy while also broadening the conceptual and empirical scope of each case study assessment.

Our case study assessments show that it is essential to actively involve the populations responsible for implementing climate adaptation measures. Adaptation efforts must translate into practice, supported by clear indicators and measurable goals that align with principles of climate justice. Engaging social actors and communities in participatory processes is fundamental for promoting social involvement and ensuring that policymakers remain accountable to their commitments, as illustrated by the case of coastal protection and development along the German North Sea coast. Coastal protection is a socio-technical endeavor structured by social processes, administrative path dependencies, and lock-ins in established approaches that limit the scope of what might, could, or should be done to technically or naturally protect the coast from projected climate change impacts. These established approaches need to be challenged, and new or alternative approaches demand projects that enable the building of communities of practice where coastal protection can be scientifically assessed, technically tested, and socially experienced and negotiated (Döring *et al* 2024, 130). Collective action has the potential to foster knowledge co-production and tackle challenges surrounding sustainable climate change adaptation.

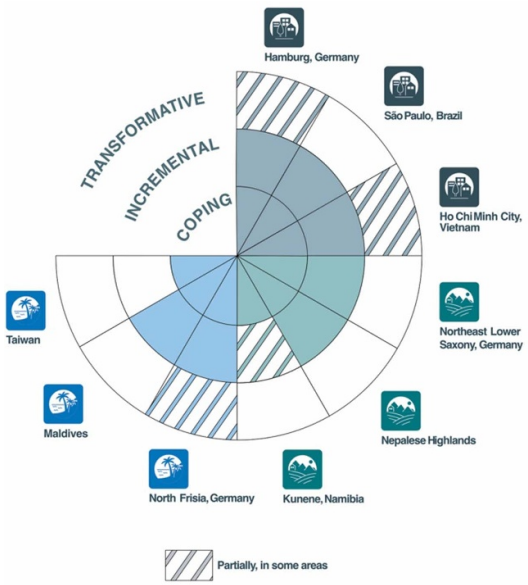

Figure 1. Climate change adaptation assessment. Reproduced with permission from CLICCS/ University of Hamburg. CC BY-NC-ND 4.0.

Figure 1 shows the result of our climate change adaptation assessment based on investigated examples of urban, rural, and coastal areas. The adaptation strategies and measures investigated are divided into coping, incremental, and transformative adaptation responses. Colored areas indicate that, for example, the process of coping is prevalent and well-established, whereas the hatched areas indicate some degree of progress that falls short of a fully achieved state, and blanks indicate that such processes were not revealed at all by the analyses.

Our analysis of nine case studies identifies crucial conditions that would make sustainable climate change adaptation a plausible climate future. In particular, long-standing political conflicts and social inequalities present structural challenges that hinder effective adaptation. Tackling social inequalities and enhancing socio-cultural capacities can bridge existing gaps between adaptive capacities and local vulnerabilities. Empirical evidence also indicates that merely establishing climate-friendly laws, regulations, and adaptation plans is insufficient, as the case study of São Paulo exemplifies. The city's political commitment to city networks and climate-related norms and practices is an important but not sufficient condition for sustainable climate change adaptation. São

Paulo demonstrates a clear mismatch between its active engagement in climate governance at different governance scales and the persistent implementation gaps on the ground. While the city plays a leading role in global and (trans)national initiatives—pioneering climate legislation and adaptation planning in Brazil—local-level challenges remain largely unaddressed. In particular, high social inequalities persist, and significant gaps in climate change adaptation continue to hinder the city's capacity to respond to climate change impacts and risks (Gresse *et al* 2024, 113).

Leveraging local experiences and knowledge regarding extreme events can significantly inform public policy decisions. Such alignment of climate change adaptation with socio-economic development promotes comprehensive objectives that consider health and well-being. Recognizing trade-offs and potential synergies among adaptation measures is essential. Coping strategies often anchor unsustainable practices, making societal support for structural transformations imperative for legitimizing and implementing comprehensive adaptation measures, as the example of small island development in the Maldives shows. Maladaptation often increases unsustainable development even further and risks the habitability of the islands at large. Generic hard protection measures often reinforce detrimental feedback loops at the expense of sustainability and biodiversity. Even atolls have expanded their land area despite regional sea level rise. Ecologically intact coral reefs remain a crucial source of natural protection for the islands (Ratter *et al* 2024b, 134).

Our analysis of social and physical dynamics in the context of climate mitigation, variability, and sustainable adaptation illustrates how ambition and implementation gaps in climate strategies are reproduced through existing power dynamics, social inequalities, and inconsistent interpretations of climate norms and practices. Addressing these gaps requires coherent political engagement across various governance scales, acknowledging the complexity of climate adaptation as a multi-faceted, wicked problem. Uncertainty in social and physical dynamics, alongside the interplay of global and local contexts, presents additional challenges for achieving sustainable climate change adaptation. Acknowledging that there are multiple agreed-upon climate goals, and various pathways to reach these goals, emphasizes the need to combat constraining conditions while bolstering enabling factors. Integrating diverse knowledge systems, especially insights from local communities and indigenous peoples, can enhance both mitigation and adaptation practices (Nakashima *et al* 2018). Local communities possess a strong situated awareness and understanding of climate change, and their local knowledge in this regard complements the scarce observational data. Together, these play a pivotal role in driving the responses to climate change-induced impacts, as the case of Nepalese highlands shows. Here, adaptation takes place on a small-scale community basis, with proactive adaptation measures that are not standalone but embedded within broader sectoral initiatives that combine adaptation and climate change mitigation. Such measures have the potential to contribute to reducing food insecurity, enhancing food sovereignty, and increasing the extent of forest and agrobiodiversity (Neupane *et al* 2024, 123).

Reducing social inequalities, fostering just negotiation processes, and creating synergies toward effective climate action can manifest transformative change. Ho Chi Minh City is considered one of the world's most vulnerable cities to climate change impacts, and sustainable climate change adaptation measures go hand in hand with measures of sustainable urban development to tackle these intertwined challenges. The Ho Chi Minh City case study shows that a stronger involvement of the urban citizenry, going beyond mere raising of awareness toward the impacts of climate change, is essential to enhance private engagement and to close existing implementation gaps (Waibel *et al* 2024, 117).

Depending on the future of climate mitigation scenarios, adaptation measures may need to take different forms because impacts vary in nature and intensity. The way forward in climate change adaptation necessitates transformative action rooted in an understanding of social drivers, internal climate variability, and structural inequities. Examples of the uneven distribution of resources range from a lack of adaptation capacities in local settings, such as poor city neighborhoods, to the major adaptation finance gaps that persist considering disagreement at international climate conferences. Yet, sustainable adaptation that includes the transformation of existing structures to address inequalities also demands meaningful engagement with diverse knowledge systems and the promotion of participatory processes that foster accountability and inclusivity.

Coping strategies for adaptation might delay or even counteract effective responses to the challenges ahead. Our case studies reveal that context-sensitive adaptation planning is necessary but not sufficient for achieving sustainable adaptation; implementation must follow the planning but is often lacking. Adaption without sustainability only buys time, whereas sustainable adaptation supports building a future.

Data availability statement

The data that support the findings of this study are openly available at the following URL/DOI: https://doi.org/10.14361/9783839470817.

Acknowledgments

The Hamburg Climate Futures Outlooks was funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under Germany's Excellence Strategy—'CLICCS' (EXC 2037, Project Number. 390683824). Contribution to the Center for Earth System Research and Sustainability (CEN) of Universität Hamburg. More than 70 researchers have contributed to the assessment.

ORCID iDs

Jan Wilkens https://orcid.org/0000-0002-6263-1540
Anita Engels https://orcid.org/0000-0003-4974-6607
Eduardo Gonçalves Gresse https://orcid.org/0000-0001-5885-0030
Andrés López-Rivera https://orcid.org/0000-0002-0497-3120
Jochem Marotzke https://orcid.org/0000-0001-9857-9900
Anna Pagnone https://orcid.org/0000-0001-9750-0711
Beate Ratter https://orcid.org/0000-0001-6647-4100

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