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The Plausibility of Climate Futures: Explaining the Methodology

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This chapter contains a brief introduction to key concepts of the current Outlook. Our focus here is on how the different elements of the overall assessment relate to each other while the following chapters will provide deeper justifications of conceptual choices for the Social Plausibility Assessment Framework (Chapter 3), for the analysis of internal climate variability and extremes (Chapter 4), and for assessing plausibility conditions for sustainable adaptation to climate change (Chapter 5). All three parts of the overall assessment are based on a combination of literature review and our own empirical research.

Worldwide efforts toward deep decarbonization are on the rise, but structural challenges for the attainment of the Paris Agreement temperature goal persist and have, in some cases, even deepened. Our past assessments came to the conclusion that limiting global warming to 1.5°C—corresponding to the most ambitious part of the Paris Agreement temperature goal—is not plausible. This lack of plausibility also applies to the scenario that global warming will only temporarily exceed but thereafter again fall below 1.5°C. Such a scenario of limited overshoot requires deep decarbonization by around 2050, which we do not deem plausible. Furthermore, increased ambition and speed to achieve deep decarbonization is required for limiting global warming to below 2°C or to prevent even larger global temperature rises. Already under current climate conditions, engaging in climate change adaptation is increasingly important, and this need will aggravate if the Paris Agreement temperature goal is missed. Therefore, exploring sustainable ways of adapting to climate change is key to promote climate-resilient and sustainable development, in addition to efforts at decarbonization.

We have already shown in previous Outlooks that deep decarbonization depends on a complex interplay of social drivers and their enabling and constraining conditions. Agreeing on the necessity of deep decarbonization as a precondition for the attainment of the 1.5°C temperature goal of the Paris Agreement by no means guarantees that society will actually move in this direction. Along the same lines, agreeing on the necessity to prepare for negative impacts of climate change and to engage in adaptation measures does not guarantee that society will actually plan, finance, and implement climate change adaptation, least of all in a sustainable manner. Moreover, if the global mean temperature rises more than 2°C compared to pre-industrial times, the physical conditions for achieving sustainable climate adaptation will have become more challenging. Therefore, drawing on the interplay between deep decarbonization (mitigation) and adaptation, the current Outlook edition addresses the overarching question:

Under which conditions is sustainable climate change adaptation plausible?

This overarching question combines an updated assessment of the social plausibility of deep decarbonization by 2050 (Chapter 3), an assessment of the physical challenges that internal climate variability and extremes pose for adaptation (Chapter 4), and the plausibility of sustainable climate change adaptation in specific regions, organized around nine case studies (Chapter 5).

Key concepts

Climate Futures: CLICCS research is organized around the concept of climate futures, by which we mean potential future states of the co-evolution of the physical climate system and society. Physical boundary conditions influence but in no way determine the way in which society will evolve. Complex social dynamics, in turn, contribute in many ways to changes in the physical boundary conditions, for example by altering the chemical composition of the atmosphere or by changing the net functions of land and water masses as sinks or sources of greenhouse gases. How these changes affect both global temperature changes and local manifestations of climate and weather is to a certain degree dependent on internal variability of the climate system.

Plausibility: Climate futures cannot be determined in a probabilistic way due to the manyfold internal complexities and irreducible uncertainties of the co-evolution of climate and society. Acknowledging the limited feasibility of a robust probabilistic assessment, we have developed an alternative framework to assess the plausibility of climate futures (Stammer et al., 2021). "Our understanding of *plausibility assessment* is based on theoretical or mental models of social dynamics and physical processes. Once these models are established, we hold available empirical evidence against the main assumptions of these models and come to a conclusion whether the world is moving toward or away from a predefined

climate future [scenario]. In light of this conclusion, we provide a conjecture on the plausibility of the climate future" (Engels et al., 2023, p. 14, emphasis by authors). What was developed with regard to social dynamics also makes sense for physical processes for which deep uncertainty exists and hence no agreed-upon quantitative measure of uncertainty can be formulated. For uncertainty that is not deep, probability distributions can be agreed upon, and plausibility is then defined such that an event may happen with appreciable probability. Whether an event will indeed occur depends not only on the future evolution of global warming but also on chance. Plausibility in any of these senses does not relate to the desirability of specific climate futures. We strive for a matter-of-factly approach to assessing climate futures, adopting a sense of sober realism because we think that it is important to know where society stands, globally speaking, compared to both overly hopeful and fatalistic expectations of the future.

Social Plausibility Assessment Framework: The Framework starts from a model of transformational change, further elaborated in Section 3.1, which acknowledges the importance of history, context, and agency (Aykut et al., 2021; Wiener et al., 2023). Plausibility refers to the level of confidence and to the strength of our knowledge judgments (Janasik, 2021), based on theoretical models of change and available empirical evidence. We understand this as a learning assessment, where repeated applications help improve the models and help them stand the test of time. We use the framework to look at the social plausibility of a specific climate future, in this case the scenario that global society will have achieved deep decarbonization by 2050. In the first Outlook, published in 2021, we identified 10 social drivers as key elements of potential change toward deep decarbonization (see Table 2.1), each influenced by specific enabling and constraining conditions and by specific relations to other drivers. In each new edition of the assessment, we screen newly available empirical evidence for changes in these conditions that might affect each driver's direction and how the drivers relate to each other. Of special interest is the generation and use of globally visible resources for climate-related societal engagement, such as new legal norms, discursive frames, or funding possibilities. Such resources form the basis of novel climate action "scripts", for example when activists develop new contentious practices, companies engage in new forms of climate reporting, or innovative climate litigation cases diffuse across national jurisdictions. New resources and scripts broaden existing repertoires of climate-related engagement and contribute to the "densification" of the global opportunity structure for climate action (see Section 3.1).

Interplay of internal climate variability and extreme events: Internal climate variability arises from the chaotic interactions within and between components of the climate system such as atmosphere, ocean, cryosphere, and land (see also Section 4.1). Since the existence of internal climate variability potentially obscures signals of anthropogenic climate change, it is important to quantify, understand, and project internal climate variability. Specific tools to address this challenge are required, such as single-model initial-condition large ensembles. 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.

Adaptation: Conceptually, we classify adaptation responses into three analytical categories (Fedele et al., 2019): First, coping strategies: short-term reactive responses that aim at immediate reactions to climatic impacts in socio-ecological systems. Second, incremental adaptation: a stepwise approach along beaten paths, focusing on sectoral or context-specific adjustments with minor systemic stability disturbance. And third, transformative adaptation: fundamental changes that encompass broader and deeper actions directed at the root causes of vulnerabilities while at the same time envisioning long-term systemic shifts (for more details and concrete examples, see Chapter 5). Coping and incremental adaptation strategies are the most frequent types of adaptation and are characterized by lock-ins and unsustainable adaptation pathways. Transformative strategies, in turn, are a key enabling, but not necessarily sufficient, condition for sustainable climate change adaptation. Responses that aim at reducing risk but create adverse effects or increase vulnerabilities are called maladaptation (for further elaboration on these concepts, see Section 5.1).

Sustainable climate change adaptation: Adapting to climate change in a sustainable manner means accounting for the broader spectrum of societal goals and socio-ecological transformations involved when designing, planning, and implementing adaptation responses. Drawing on Gresse et al. (2023), we define sustainable climate change adaptation as the process of adapting to actual and expected climate change and its impacts by significantly reducing actual and potential conflicts and exploiting synergies between climate action and other sustainable development goals. Hence, a sustainable adaptation response necessarily has to extrapolate the various ranges of climate action while also fostering sustainability transformations, that is, multi-sectoral and system-wide shifts that foster human development while protecting and upholding the Earth's life-support systems' resilience (see also Section 5.1).

Context conditions for the plausibility of sustainable climate change adaptation: Organized around nine local and regional case studies, we focus on the interaction of societal systems with their various social, cultural, spatial, temporal, and natural environments. Based on an inductive rationale, the investigation builds on a commonly structured and joint assessment of empirical studies and conceptual reflections taken from these case studies. They examine, analyze, and assess the barriers to and the possibilities for sustainable climate change adaptation across different regional contexts. To account for locally specific and diverse ways of knowing (cf. Petzold et al., 2021; Wiener et al., 2023), the case studies were written by interdisciplinary groups of authors and in co-authorships with local experts situated in the respective case study context. This was implemented in accordance with calls to integrate various knowledge forms alongside current adaptation strategies, as for example acknowledged in the fifth and sixth Assessment Reports by the Intergovernmental Panel in Climate Change (IPCC). This integration is not merely seen to enhance the efficacy of adaptation efforts but also deemed essential for fostering ethical and sustainable adaptation practices (Nakashima et al., 2018; de Coninck et al., 2018, Petzold et al., 2020). In light of these assessments, we empirically reconstruct the conditions that make sustainable climate change adaptation plausible in each specific and place-based case.

Integrating the building blocks of the Outlook 2024

Assessing the plausibility of deep decarbonization by 2050 creates a first important building block for the overarching question of the plausibility conditions for sustainable climate change adaptation. If it is not plausible, or—as the assessment in Chapter 3 will show—even becoming less plausible that deep decarbonization will be achieved by 2050, this implies a global warming of more than 1.5°C that will persist until the end of the century; a warming level that, in turn, affects the physical boundary conditions for the future of human society. Understanding these physical boundary conditions helps define the challenges for adaptation to climate change impacts in different regional and local settings.

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. Therefore, the interplay of internal climate variability and extreme events is the second important building block that affects the plausibility conditions for sustainable climate change adaptation. Each example discussed in Chapter 4 illustrates a particular fundamental point relevant for the plausibility of sustainable climate change adaptation: the capability of climate models to represent extremes (here: precipitation), the attribution of extreme events to human influence (here: marine heatwaves), and the probability of compounding extreme events (here: extreme heat in multiple breadbasket regions). In this fundamental sense, these examples foreshadow the relevance of the physical processes and results for the adaptation challenges that are assessed in Chapter 5.

The nine case studies and the combination of empirical analyses and theoretical reflection create the third important building block for assessing the plausibility conditions for sustainable climate change adaptation. The case studies analyze different types of adaptation responses (or lack thereof) and address the extent to which social systems are able to adapt to climate change, that is, the context-specific limits and limitations of adaptation. While the scenario for the plausibility assessment of the first building block—achieving deep decarbonization by 2050—has a clear time horizon, the scenario for sustainable climate change adaptation spreads into many different place-specific scenarios, each depending on the particular local manifestations of climate change, the expected climate extremes including their inherent uncertainties, and unclear time horizons. Which combination of sustainability goals, which level of adaptation, and which limits of adaptation make a good scenario for assessing the plausibility conditions in a specific local or regional setting is always subject to negotiation. Therefore, the nine case studies apply a common set of questions but are in themselves inductive in defining which type of climate change impact is most socially relevant, and what would actually constitute criteria for adapting to these impacts in a sustainable way.

Considering the challenges of such diverse geographical and temporal scales as well as the context-specific understandings of what it means to adapt to climate change in time, we come to a very differentiated answer to the overarching question of the plausibility conditions for sustainable climate change adaptation (Chapter 6).

Who are we? How do we work?

"We" are a group of 73 authors working together in the Cluster of Excellence Climate, Climatic Change, and Society (CLICCS) at the Universität Hamburg, its partner institutions, chiefly among them the Max Planck Institute for Meteorology and the Helmholtz-Zentrum Hereon, and from within the regions assessed in the nine case studies, contributing with practical knowledge and local perspective to climate change adaptation efforts in these different regions. While our goal is to provide a global assessment, we are aware of the risk of over-representing northern European views and understandings of the dynamics we are observing and of marginalizing views and voices from the Global South, or simply from places

other than Northern Europe, as well as from epistemic perspectives other than the ones typically employed in mainstream climate science. In order to minimize this risk, we explicitly include assessments of dynamics in countries of the Global South. We made specific efforts to represent different epistemic perspectives in the literature reviews to also draw from scientific fields that are typically not represented in mainstream climate science, and to include diverse ways of knowing by including authors and perspectives from the Global South. We invited authors from outside of CLICCS to make sure that we write on specific regions together with authors from these regions (Brazil, Maldives, Nepal, Taiwan, and Vietnam). Finally, we invited authors from the Global South to review two previous versions of this Outlook. As we rely on different combinations of original data produced in CLICCS, existing data bases on many different topics, and deep literature reviews, we explain in every chapter the specific data foundation that the assessment contained therein is based on.

Learning assessment: Conceptual developments between Outlook versions

We have introduced a number of conceptual developments in this new Outlook version. Table 2.1 summarizes how key conceptual choices have been refined, added, and deepened. Each Outlook is organized around a new overarching question, which also guides us in the way we integrate the different assessment parts. While Outlook 2021 focused on deep decarbonization and temperature changes, Outlook 2023 added a new framework for Sustainable Climate Change Adaptation, which is now, in this Outlook, applied to 9 case studies. The number of authors has risen continuously from 43 to 73.

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TABLE 2.1

Learning Assessment: Conceptual developments between Outlook versions

	Outlook 2024	Outlook 2023	Outlook 2021
Overarching question	**Under which conditions is sustainable climate change adaptation plausible?**	**What affects the plausibility of attaining the Paris Agreement temperature goals?**	**Is it plausible that the world will reach deep decarbonization by 2050?**
Social Plausibility Assessment Framework	**Relationality** (push/pull dynamics) between social drivers	**Densification of climate action** (scripts and repertoires of Global Opportunity Structure)	**10 social drivers** Enabling and constraining conditions and resources of Global Opportunity Structure
Social drivers	**Stronger emphasis on drivers as processes:** ► Transnational Initiatives → Transnational Cooperation ► Climate Protests and Social Movements → Climate Activism and Social Mobilization ► Consumption Patterns → Consumption Trends	**Widening of one driver:** ► Journalism → Media	**10 social drivers** ► UN Climate governance ► Transnational initiatives ► Climate-related regulation ► Climate protests and social movements ► Climate litigation ► Corporate responses ► Fossil-fuel divestment ► Consumption patterns ► Journalism ► Knowledge production
Physical processes	**Three example interplays of regional variability and extremes:** ► Precipitation ► Marine heatwaves ► Extreme heat in multiple breadbasket regions	**Physical Plausibility Assessment Framework. Six example physical processes:** ► Permafrost thaw ► Arctic sea-ice decline ► Polar ice-sheet melt ► Atlantic Meridional Overturning Circulation instability ► Amazon Forest dieback ► Regional climate change and variability	**Temperature trends for the 21st century**
Sustainable Climate Change Adaptation	Inductive model of conditions of sustainable climate change adaptation via nine case-studies	Distinction between coping-incremental-transformative. Definition of sustainable climate change adaptation	Not discussed
Authors	73 from CLICCS and external partners from Brazil, Maldives, Nepal, Taiwan, Vietnam	63 from CLICCS only	43 from CLICCS only