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HAMBURG CLIMATE FUTURES OUTLOOK



Assessing the plausibility of
deep decarbonization by 2050



Universität Hamburg

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CLUSTER OF EXCELLENCE
CLIMATE, CLIMATIC CHANGE,
AND SOCIETY (CLICCS)

About CLICCS

Researchers from a wide range of disciplines have joined forces at the Cluster of Excellence CLICCS (Climate, Climatic Change, and Society) to investigate how climate and society will co-evolve. The CLICCS program is coordinated through Universität Hamburg's Center for Earth System Research and Sustainability (CEN) in close collaboration with multiple partner institutions and is funded by the Deutsche Forschungsgemeinschaft (DFG).

About the Outlook

In the annual *Hamburg Climate Futures Outlook*, CLICCS researchers make the first systematic attempt to assess which climate futures are plausible, by combining multidisciplinary assessments of plausibility.

The inaugural 2021 *Hamburg Climate Futures Outlook* addresses the question: Is it plausible that the world will reach deep decarbonization by 2050?

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Key Findings

There are many possible futures of climate, but not all possible futures are also plausible. Because climate futures arise from a complex combination of social and physical dynamics, estimating their plausibility requires insights from multiple disciplines. The inaugural *Hamburg Climate Futures Outlook* makes the first systematic attempt to assess the plausibility of various climate futures. We deem climate futures to be plausible if we expect them to unfold with appreciable probability, given the existing evidence from the physical and social worlds.

In this *Outlook*, we combine complementary assessments of physical and social dynamics, starting with a review of the techno-economic plausibility of very high and very low CO₂ emissions scenarios. We find evidence from the scenario literature which suggests that very high emissions scenarios are internally inconsistent, due to the extent of economic damages from climate change, the falling cost of clean energy, and limits to recoverable coal reserves. The literature also provides some degree of evidence against the plausibility of large-scale deployment of carbon dioxide removal technologies, which is a common requirement of very low emissions scenarios.

Very low emissions scenarios, if they are designed to achieve the Paris Agreement's 1.5°C target, additionally require decarbonization of the global economy by around the year 2050. Many known technical or economic options would in principle achieve this decarbonization goal in time. Yet existing assessments have only begun to evaluate the plausibility of the societal transformations necessary for deep decarbonization. Such a plausibility assessment requires the definition of the political, economic, and cultural conditions under which the necessary transformations become plausible. The existing empirical evidence can then be weighed against this theoretical model of transformation.

We therefore propose the Social Plausibility Assessment Framework, a framework that enables the analysis of the social drivers of decarbonization, their enabling and constraining conditions, and emerging resources and structures that could influence plausible future developments of these drivers. None of the ten social drivers studied show sufficient movement toward deep decarbonization. Some of these drivers—namely United Nations climate governance, transnational initiatives, climate-related regulation, climate litigation, fossil fuel divestment, and knowledge production—support decarbonization, but without sufficient momentum to drive deep decarbonization by 2050. For two drivers—climate protests and social movements, and journalism—the momentum toward or away from deep decarbonization by 2050 could not be assessed. Two further drivers—consumption patterns and corporate responses—currently oppose decarbonization.

Therefore, we find that unless the enabling conditions of social drivers deliver a radical boost to these drivers in the coming years, reaching worldwide deep decarbonization by 2050 is not plausible (see Figure 1). This result implies that, even if techno-economic options for decarbonization are theoretically available, reaching deep decarbonization by 2050 constitutes a societal challenge that may well be much larger than assumed by many.

However, six of the evaluated social drivers show movement toward decarbonization, and many drivers offer resources that could be utilized by societal actors to strengthen the enabling conditions and therefore increase the plausibility of decarbonization in the future. Therefore, partial decarbonization by 2050 remains plausible under our current social assessment.

The finding that deep decarbonization by 2050 is currently not plausible adds to the evidence speaking against the overall plausibility of very low emissions scenarios for the entire twenty-first century. Combined with the recently identified, narrower range of climate sensitivity, this indicates that limiting global surface warming below about 1.7°C by 2100 is currently not plausible.

The new climate sensitivity range, combined with our techno-economic plausibility assessment, also constrains the upper bound of plausible warming, so that global surface warming above about 4.9°C by 2100 is likewise currently not plausible.

This assessment of plausible climate futures represents a judgement that synthesizes currently available evidence. However, social agency can always produce departures from expected trajectories. For deep decarbonization by 2050 to become plausible, much will depend on public pressure via protests, organized action, and climate litigation, so that governments around the globe are increasingly driven towards policies that support change, not only via goals and pledges, but by consistent action. Furthermore, the complex interrelations within social dynamics can produce unforeseen disruptions, and events like the COVID-19 pandemic can happen at any time. Should additional evidence, including that from unexpected events, necessitate modifications of our assessment, this will be reflected in future editions of the *Hamburg Climate Futures Outlook*.

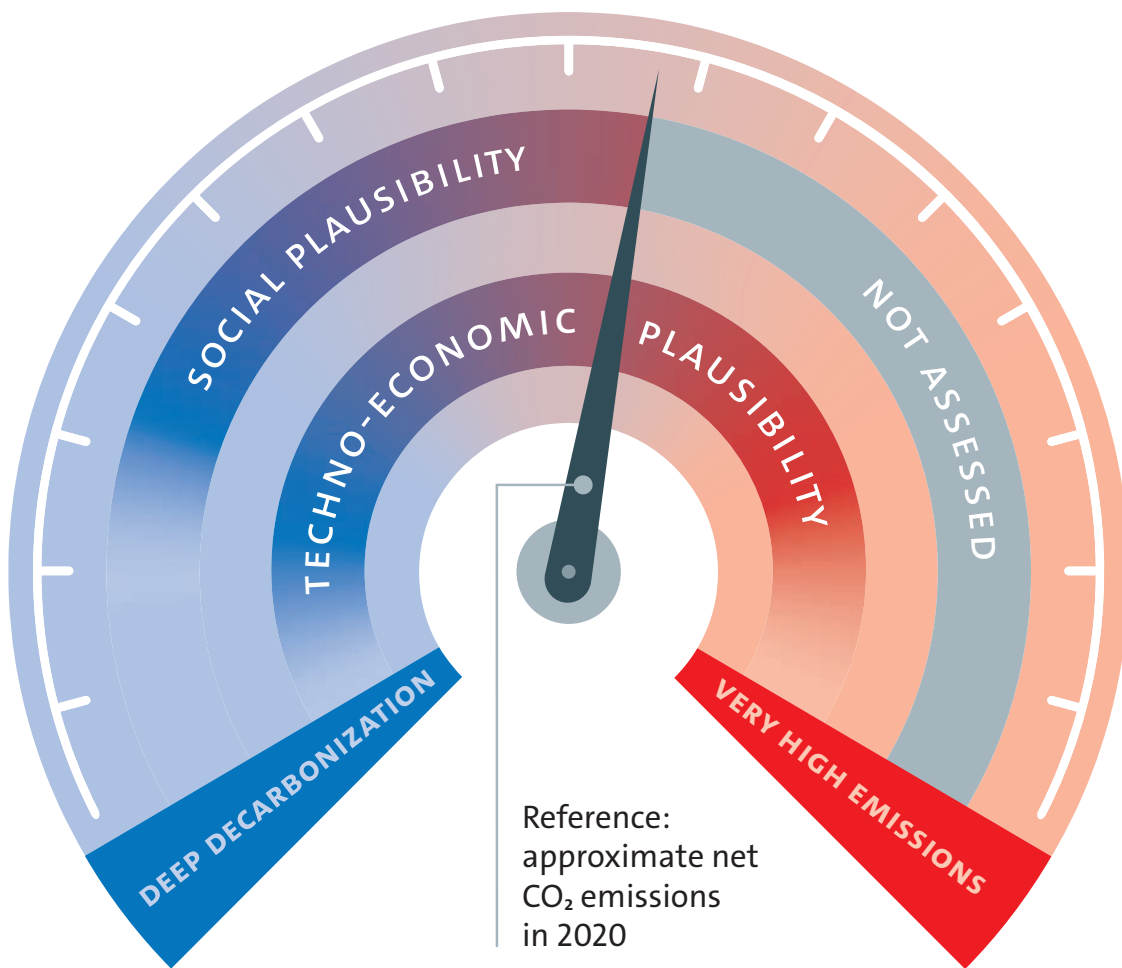


Figure 1: Plausibility of net global CO₂ emissions by 2050. The speedometer shows the wide range of possible emissions in the year 2050 as described in existing emissions scenarios. Emissions could reach net-zero by 2050 (deep decarbonization) or could increase up to a doubling of current emissions (very high emissions). Approximate emissions in 2020 are indicated by the speedometer needle. Here we find a reduced range of plausible emissions scenarios, supported by a techno-economic plausibility assessment (Chapter 3) and a social plausibility assessment (Chapter 5), indicated by the shaded bands. Increasing emissions are not yet considered in the social plausibility assessment (gray band).

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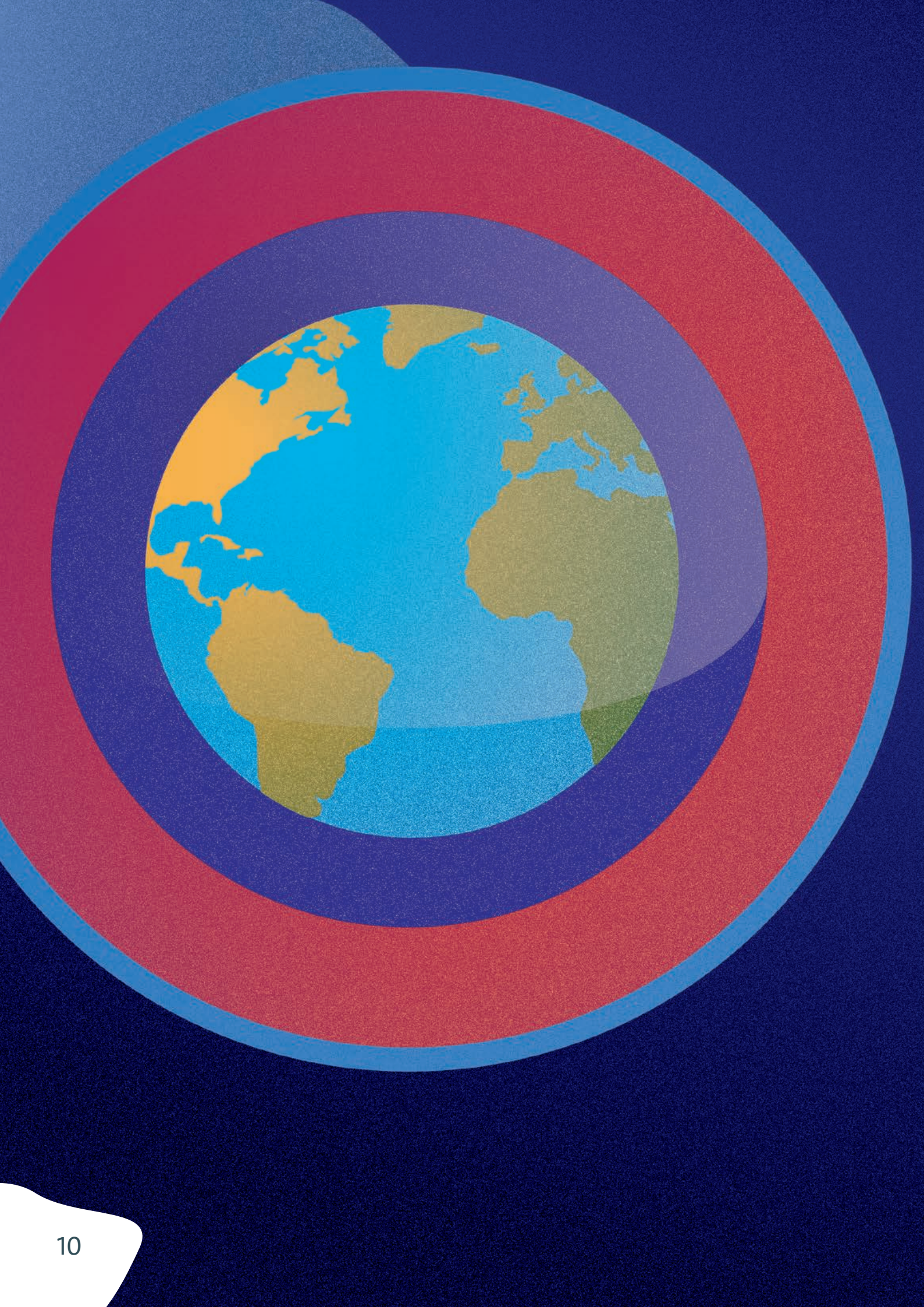
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PART I

Plausibility assessment of climate futures



1

Introduction

1

Introduction

The purpose of the annual *Hamburg Climate Futures Outlook* (hereafter *Outlook*) is to assess which climate futures—future joint developments of climate and society—are possible and which are plausible. This and future *Outlooks* are dedicated to help answer questions such as: Toward which future is the Earth’s climate moving? What might the climate look like in 2050, or in 2100? And what type of society might evolve together with the changing climate? We cannot accurately predict this future, but we can use our joint understanding of the physical and the social worlds to identify which climate futures are plausible.

Physical climate is a global system with regional manifestations; it is driven by influences such as greenhouse gases emitted by human activity, and it is additionally altered by internal variability—fluctuations, such as the inevitable differences between two consecutive summers. Society is a complex system driven by divergent dynamics and strong moments of inertia. Joint development of these two systems occurs because climatic change, in all its regional and local manifestations, influences but does not determine the maneuvering space of social actors. Social dynamics eventually lead to greenhouse gas emissions, which in turn influence the climate system.

We understand *possible* climate futures as those future states that are consistent with our joint understanding of climate and social dynamics. *Plausible* climate futures denote the subset of those possible future states that we expect to unfold with appreciable probability, given the existing evidence from the physical and social worlds (see Figure 1). Physical plausibility is derived here from a quantified estimation of the responses of the physical climate system to specified human-induced perturbations, taking into consideration internal variability. The social plausibility of a particular climate future is derived from theories of social change and a theoretical understanding of the political, economic, and cultural conditions under which such transformations can unfold. This theoretical model leads us to identify relevant social drivers of change. The core of our social plausibility assessment is to weigh existing empirical evidence against the theoretical model of transformation.

The *Outlook* fills a crucial gap in the existing assessments of future climates (see Box 1). Whereas previous approaches frequently ask which futures are desirable, or what pathways might lead to desirable futures, we deliberately shift our focus toward the question “are specific climate futures plausible?”, regardless of whether they are desirable or not. Our assessment of plausibility is based on our

understanding of social transformations and their drivers, combined with empirical evidence on the direction that these drivers are currently taking (see Chapters 2 and 4). For this assessment, we draw on expertise from within the research cluster Climate, Climatic Change, and Society (CLICCS) at Universität Hamburg, which lends the *Hamburg Climate Futures Outlook*.

Among existing recurring climate assessments, the CLICCS approach is unique in that it jointly assesses both the social plausibility of global emissions futures and the physical plausibility of resulting temperature trajectories and extremes. Not only is the combined assessment of physical and social plausibility unique, our approach to social plausibility in the CLICCS assessment framework (Chapter 4) is entirely new. We go deeper than techno-economic or demographic drivers like population growth, and examine underlying social drivers which bring about the social dynamics that can change global emissions futures. However, this new Social Plausibility Assessment Framework is not yet able to assess varying degrees of plausibility for a range of specific emission scenarios. Instead, we use the framework to assess one politically relevant scenario that represents an outer limit of the range of possible future scenarios—*deep decarbonization by 2050*. Numerous existing studies suggest that *deep decarbonization by 2050* is still technologically possible. Here we inquire whether such a future is not only possible but also plausible.

This first *Outlook* 2021 thus explores the question: **Is it plausible that the world will reach deep decarbonization by 2050?**

We draw on a synthesis of systematic literature reviews, secondary data, and our own research. Our question translates the temperature goals of the 2015 Paris Agreement—holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels (UNFCCC, 2015)—into a scenario that encapsulates the required social and technical transformations consistent with these goals.

Chapter 2 discusses the epistemological challenges of assessing the plausibility of climate futures; it also justifies the chapter sequence we have chosen. Chapter 3 explores the plausibility of existing model-based emissions scenarios, testing their assumptions and identifying where critical social dynamics have been omitted. Chapter 4 introduces the Social Plausibility Assessment Framework for assessing the plausibility of future social dynamics.

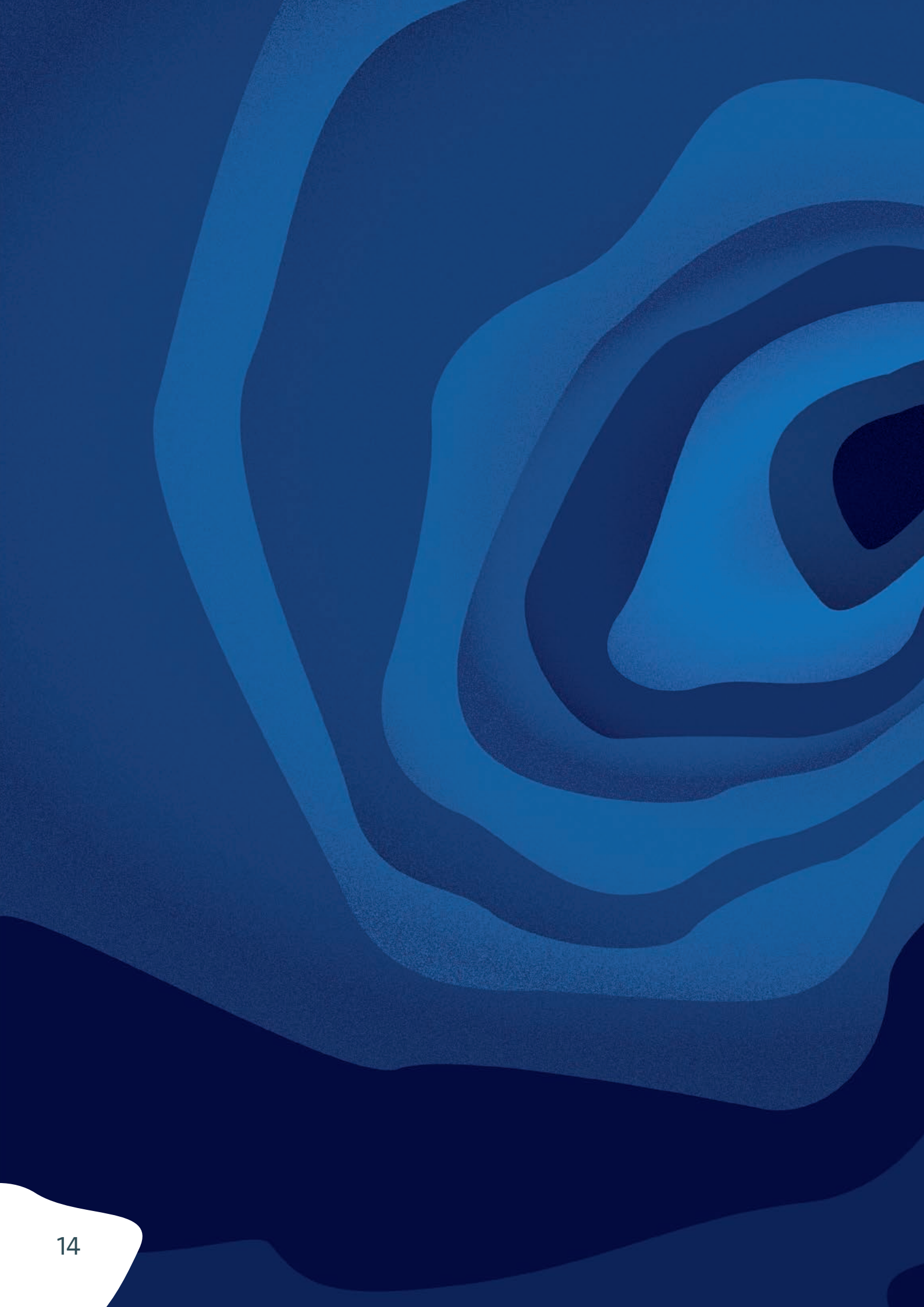
This methodology is then applied in Chapter 5, which summarizes the social drivers and dynamics that influence the pathways toward or away from the scenario deep decarbonization by 2050. The in-depth assessment that serves as the foundation of Chapter 5 is found in Part II (Chapter 8) of this Outlook. Chapter 6 turns to physical plausibility, focusing on recent advances in assessing expected temperature trends throughout the twenty-first century.

Four boxes are interspersed between the chapters, providing brief summaries on overarching topics, including the distinction between the *Outlook* and other climate assessments (Box 1), the synergies and trade-offs between climate mitigation and other sustainability goals (Box 2), how *diverse ways of knowing* support the plausibility assessment of climate futures (Box 3), and how the current COVID-19 pandemic influences climate futures (Box 4). Answers to frequently asked questions are compiled at the end of this document, in order to explain and briefly summarize key aspects of the *Outlook*.

Scenarios of future developments are not merely descriptions, detached from the future they describe. They can change the way in which the future is imagined by actors, by introducing new conceivable courses of action or by reinforcing established ones. In doing so, they can influence the way and direction in which the future unfolds. Communicating the expectation of severe climate change can incite urgent action, but also fatalistic behavior. Alternatively, communicating the expectation that climate change can plausibly be mitigated could lead to a stronger motivation for mitigation efforts, but could also lead to complacency and a decreased sense of urgency. Once published, all assessments become part of the social world and can affect social dynamics in unforeseen ways. Chapter 7 therefore addresses the implications of our assessment: Achieving deep decarbonization by 2050 is currently not plausible, but nor is it impossible, and the *Outlook* identifies enabling conditions that would allow the plausibility of this outcome to increase.

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2

Epistemological challenges for assessing plausibility

2.1 Identifying physical plausibility

2.2 Identifying social plausibility

2.3 Combining physical and social plausibility assessments

BOX I *The Hamburg Climate Futures Outlook* and other assessments of climate futures

2

Epistemological challenges for assessing plausibility

In order to separate plausible climate futures from those that are merely possible, we must grapple with two radically contrasting disciplinary approaches to probability. In the physical climate sciences, there is a well-established practice of estimating the probability of future states of the climate, given assumptions about greenhouse gas emissions and other external influences. However, most social sciences have good reasons to avoid any probabilistic description of future states of society. Our starting point for working on future societal developments (including the economy, politics, and culture) is to assume that the future is pre-conditioned

but undetermined. Future social developments are pre-conditioned in that they are partly influenced by the past or by past decisions, which can favor particular pathways (*path dependency*) and lend the social system a certain inertia, inhibiting rapid change. However, in the social system, departures from the expected path (*path departure*) and disruptions are quite common too, causing even very basic constituents of the social system to change in unexpected ways. Here we discuss how the physical and social science approaches to future changes can be brought together for the purpose of assessing plausibility.

2.1

Identifying physical plausibility

In the physical climate sciences, estimates of possibility and plausibility derive from knowledge of the deterministic and stochastic behavior of the climate system. Deterministic behavior refers to mechanisms that determine the impact of changing external influences in ways that are known in principle, even if they cannot be quantified with certainty. For example, there are well-established mechanisms that link increasing atmospheric CO₂ concentrations to future long-term global surface warming, and the quantification of that future warming can be expressed as a probability range (e.g., Collins et al., 2013).

In addition, climate can vary without any external influence. Local manifestations of seasons are examples of such variation: no two summers are exactly alike. Global surface temperature can also naturally fluctuate about an average state, even on decadal timescales. This type of internal variation can be considered a stochastic and largely unpredictable process. However, scientific investigation of the stochastic processes indicates that not all variations are equally likely to occur on particular timescales, so that internal variability, too, can be expressed as a probability range (e.g., Maher et al., 2019).

The full range of physically possible climate futures is derived from a combination of the deterministic behavior, internal variability, and their uncertainty distributions (e.g., Marotzke and Forster, 2015). The associated probabilities make futures either merely possible—if they can conceivably occur but have low probability—or plausible, if they can occur with appreciable probability.

2.2

Identifying social plausibility

The social dynamics of climate futures are too complex to be described probabilistically. And yet, not all possible scenarios of a societal future seem equally plausible, since there are certain qualities of the present that can be interpreted as pointing toward or away from a particular future (Pulver and Vandevier, 2009; Staman et al., 2017; Bas, 2021). For some dynamics in the social system, trend extrapolations are possible and have predictive power. But in the past, unforeseen events and disruptions have also ended existing trends and led to new pathways. The fall of the Berlin Wall is an example of such an unforeseen and disruptive event. Other observed deep transformations of the past have taken place not as the outcome of planned action, but rather as accumulated side effects (Sinha, 2018) or as slow cultural change that evolves over decades or even centuries, such as the gradual global diffusion of carbon-intensive lifestyles before they entered an exponential-growth phase in the second half of the twentieth century.

Some existing methods attempt to improve prediction capacities in the social sciences (e.g., Armstrong, 2001; Taleb, 2007; Ungar et al., 2012; Mellers et al., 2015; Tetlock and Gardner, 2016), and some attempts at prediction have even been successful (Silver, 2012). However, these forecasts are usually targeted only at partial components or one-off events in the social system, such as elections, or trends in the financial market. Yet, the challenge for understanding the social plausibility of climate futures is that society, with all of its internal driving forces, cannot be reduced to partial components such as elections. Society is highly complex and does not have a center from which it can be organized hierarchically and controlled effectively in the name of a global “we”, although this misconception still implicitly informs much thinking about transformations in the Anthropocene (Grundmann and Rödder, 2019; Neckel, 2021). Attempts to control some part of society always produce unintended consequences and spillover effects in other parts. Examples include implementing strict anti-pollution controls, when the pollution is simply shifted to other locations, or the closure of a heavily frequented road for through-traffic, when traffic finds its way around the closed road.

To deepen our understanding of social change, we examine the interplay between societal actors and structures. Societal actors can bring about change when powerful individuals or groups, such as governments or large multinational corporations, make decisions that influence social behavior. Change can also be brought about by individuals with less power when they gather in large numbers under a common purpose, such as in social movements, or when the aggregated behavior of many individuals shifts, such as when consumption patterns and investment patterns change over time. Societal structures describe the social context within which the actors operate; this context can precondition plausible actions and thus create path dependencies. However, structures can also be modified by societal actors—sometimes drastically—leading to new conditions and new opportunities for future social behavior, or to departures from the expected path. One example of such structural change would be a switch of the global political system from one type of multilateral world order to another (Viola, 2020), modifying the preconditions for achieving global agreements. A further example is the industrial revolution and the profound transformations it brought to capital owners and workers.

Identifying social plausibility therefore requires a methodology that recognizes the future as simultaneously undetermined and pre-conditioned. Social transformation, when it occurs, can be sudden, but it can also be slow and evolutionary. To assess the plausibility of climate futures, the methodology must also acknowledge the potential for social change, and that even the fundamental constituting elements of the observed system can change and create entirely new conditions for future emissions pathways (see Chapter 4). We assess social plausibility by developing a theoretical model of transformation, and by using this model to interpret existing empirical evidence.

2.3

Combining physical and social plausibility assessments

Narrative scenarios of future climate offer a common ground on which to combine social and physical plausibility of climate futures. The newest IPCC Assessment Reports, for example, assess plausible physical dynamics conditioned on a set of scenarios called the Shared Socioeconomic Pathways (SSPs). These scenarios describe potential future social and techno-economic dynamics that might lead to particular emissions pathways. Any stated plausible range of surface warming is only valid assuming a particular emissions pathway, which in turn assumes that the underlying social and techno-economic dynamics indeed unfold.

The SSPs are designed to describe a wide range of social futures (Riahi et al., 2017); they include futures with international conflict, futures with international cooperation, and futures with either high or low challenges to mitigation and adaptation. The range of possible social dynamics are thus left relatively unconstrained across the SSPs. By contrast, the SSPs comprise substantial techno-economic constraints, in that they are usually the result of an economic optimization that considers the cost of various technological options, especially in the energy sector. Based on the existing literature, Chapter 3 assesses the techno-economic assumptions behind the existing SSPs, providing a reduced range for techno-economic plausibility of emissions scenarios.

Since the techno-economic assessment omits essential aspects of social dynamics for climate futures, we add a critical extension. We propose a scenario suitable for a social plausibility assessment—*deep decarbonization by 2050* (Chapter 3). We assess this scenario using the Social Plausibility Assessment Framework, which we develop and present here for the first time (Chapters 4 and 5). In a further step, we ask what the relatively specific techno-economic assessment and the wider social plausibility assessment imply for the physical plausibility of global surface warming scenarios. This allows us to present the first combined social and physical plausibility assessment of global surface warming (Chapter 6), which represents a key advancement in the science of climate futures.

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BOX I The *Hamburg Climate Futures Outlook* and other assessments of climate futures

The first *Hamburg Climate Futures Outlook* evaluates the plausibility of achieving deep decarbonization by 2050, which is considered necessary to limit the average global surface warming to 1.5°C above pre-industrial levels and meet one of the core objectives of the Paris Agreement. The *Outlook* is by no means the first initiative to assess pathways that might lead to such a future. It joins reports such as the *IPCC Special Report on Global Warming of 1.5°C (SR1.5)*, the *UNEP Emissions Gap Report* and reports from Climate Action Tracker and The World in 2050 initiatives. Why then, do we need another assessment of climate futures?

There are three critical aspects of the *Hamburg Climate Futures Outlook* that make its contribution to the existing reporting landscape unique.

1. Assessment of social drivers

Existing reports assess what is practically and technically required to achieve net carbon zero—such as coal phase-out and decarbonization of transport and industry (e.g., the SR1.5 and *UNEP Emissions Gap Report*)—but not the social drivers that would motivate and legitimate such a change. Existing reports acknowledge the importance of social drivers: The *UNEP Emissions Gap Report* for example describes *drivers of ambition* such as political motivation or social consumption preferences, while the SR1.5 acknowledges that the success of the transition is related to actor interactions and social values (de Coninck et al., 2018: 383). However, the analysis of social drivers remains largely descriptive rather than evaluative. The *Outlook* seeks to fill this gap by performing a systematic assessment of social drivers that might motivate a transition to deep decarbonization, including their existing trajectory and potential future evolution.

The focus on social drivers also allows the *Outlook* to distinguish political intentions from deeper motivating dynamics. Whereas the Climate Action Tracker (New Climate Institute and Climate Analytics, 2019) assesses the policy intentions of nation states, the *Outlook* investigates the trajectories and dynamics of social drivers that may motivate political action in the first place. These drivers include for instance, climate protests and social movements, consumption patterns, and corporate responses (see Chapter 5).

2. Analytical not normative

Futures researchers often ask not only which futures are plausible, but which are desirable. In doing so they take a deliberate normative stance, which recognizes that the likelihood of a particular future is strongly influenced by societal motives or intentions to move toward that future (Robinson, 2003). For example, the reports of The World in 2050 initiative propose an aspirational narrative for achieving the Sustainable Development Goals (SDGs), including deep decarbonization by 2050 (TWI - The World in 2050, 2018). The research focus of The World in 2050 therefore becomes how such a future can be achieved, leading to the proposal of cross-cutting transformations in the areas of human capacity and demography, consumption and production, decarbonization and energy, food, biosphere and water, smart cities, and the digital revolution.

Although the *Outlook* also recognizes the power of societal motives and intentions, its emphasis is placed on analyzing the present available evidence of relevant social dynamics. The *Outlook* is therefore not concerned with shaping the future, but with analyzing its plausibility based on the present.

3. Social plausibility rather than feasibility

Some existing reports explore aspects of climate futures using the concept of *feasibility*. The SR1.5, for example, analyzes the feasibility of mitigation and adaptation options based on potential barriers in six different dimensions. Although the *Hamburg Climate Futures Outlook* also considers feasibility in relation to carbon-dioxide removal methods (see Chapter 3), its goal is to assess plausibility. *Feasibility* is primarily concerned with the potential for barriers to a particular pathway, or the absence of such barriers (Allen et al., 2018). Some of the societal indicators used to assess feasibility of mitigation options in SR1.5 include absence of barriers in the areas of political acceptability, public acceptance, and institutional capacities (de Coninck et al., 2018). However, *plausibility* is concerned not only with barriers but with all the factors that influence how likely a pathway may be, so that a feasible pathway need not necessarily be plausible. As the discussion in Chapter 4 and the analysis in Chapters 5 and 8 show, making deep decarbonization by 2050 socially plausible requires more than public acceptance, it requires a strong political and societal will to move toward deep decarbonization and indeed to overcome the barriers that reduce the feasibility of such a socioeconomic transformation.



Plausibility of model-based emissions scenarios

- 3.1** Climate scenarios used in the IPCC
- 3.2** The scenario framework of this Outlook
- 3.3** Plausibility of existing scenarios
- 3.4** Deep decarbonization by 2050
- BOX II** Synergies and trade-offs in the assessment of plausible climate futures

3

Plausibility of model-based emissions scenarios

Scenarios help explore the future of climate by integrating many diverse aspects of the physical and social system. The goal of combining the techno-economic aspects of climate change with the physical consequences of resulting emissions has driven much of the history of model-based scenario development within the IPCC community (Section 3.1). This *Outlook* starts its assessment with the most recent generation of scenarios used in the IPCC, the SSPs (Riahi et al., 2017), and especially the high-

priority subset of SSP scenarios, which are used as input for the newest generation of comprehensive climate models (O'Neill et al., 2016; see Section 3.2). Section 3.3 assesses the techno-economic plausibility of the high-priority SSP scenarios. In Section 3.4, we propose the scenario *deep decarbonization by 2050* and bridge the gap between the techno-economic and social plausibility assessments of low emissions climate futures.

3.1

Climate scenarios used in the IPCC

Scenarios have long been an important structuring element in thinking about climate futures. IPCC assessments have over the last decade relied on a scenario framework that builds on two main elements: Representative Concentration Pathways (RCPs), which describe stylized forcing outcomes (van Vuuren et al., 2011), and Shared Socioeconomic Pathways (SSPs), which describe typical evolutions of the world without additional climate policies (O'Neill et al., 2014). These are complemented by Shared Policy Assumptions (SPAs) that enclose key characteristics of climate policies, concerning both mitigation and adaptation (Kriegler et al., 2014). All three were conceived as interdependent; RCPs and SSPs form a so-called *scenario matrix*, to which SPAs were to add a third dimension (van Vuuren et al., 2013). In practice, policy assumptions have been implemented as forcings that lead to change within the SSP-RCP matrix, without necessarily adding a third dimension. The rationale for this framework stems from practical considerations concerning the sequential organization of disciplinary modeling exercises for IPCC assessments, but also from reflections on the ways to ensure policy-relevance of simulations while avoiding policy prescriptiveness (Moss et al., 2008; Moss et al., 2010).

The SSP-RCP scenario framework is inscribed in a long history of scenario-building, but also departs from approaches used in earlier IPCC assessments. Previous approaches include the SA90-scenarios for the IPCC First Assessment Report (IPCC, 1990: Appendix I), the IS92 scenarios for the 1992 IPCC

Supplementary Report and the Second Assessment Report (Leggett et al., 1992; Alcamo et al., 1995), and the scenario family for the Third and Fourth Assessment Reports based on the Special Report on Emissions Scenarios (SRES; Nakicenovic et al., 2000). These scenario architectures not only shape the ways in which researchers from different disciplines collaborate in the IPCC process, they also entail important yet often implicit assumptions about societal dynamics and social change (Garb et al., 2008), global politics and governance (Parikh, 1992; Dahan-Dalmedico, 2008), technological innovation (Pielke Jr et al., 2008), and possible solution spaces (Beck and Mahony, 2017).

Like its predecessors, the SSP-RCP scenario matrix also embodies specific views on the needs of the policy process in terms of prospective expertise (Cointe et al., 2019). Such views changed over the years (Girod et al., 2009). One of the most important long-standing debates concerns the inclusion of *business-as-usual* scenarios in contrast to *intervention* or *climate policy* scenarios. While the IPCC First Assessment Report included one business-as-usual scenario and three intervention scenarios, the IS92 scenarios include one business-as-usual and five non-intervention scenarios, which represent different possible evolutions of the world. The SRES scenarios are exclusively based on non-intervention baseline scenarios (six illustrative families, including three high-growth pathways, a global and a local sustainability pathway, and a regional growth pathway, making a total of 40 scenarios), which describe contrasting evolutions of the

world, independent of climate policy measures. The SRES scenarios have been criticized in turn for being apolitical; they do not include explicit policy choices, although their results implicitly embed climate stabilization measures (Webster et al., 2008). This has been partly addressed in the SSP-RCP matrix. The SSPs also represent stylized evolutions in the absence of climate policy: a world of sustainability and equality (SSP1); a “middle of the road” world that perpetuates historical trends (SSP2); a fragmented world of regional rivalry (SSP3); a world of increasing inequality and low sustainability (SSP4); and a world of unconstrained growth and fossil fuel use (SSP5). However, SSPs can subsequently be combined with mitigation targets (in the form of RCPs) to test how these targets can be achieved within the context of varying assumptions about socioeconomic developments and policy choices.

A second debate concerns the transparency and usability of scenarios. Hence, the SRES scenario family is the first to include explicit narrative storylines. By making some of the assumptions behind the scenarios explicit, these storylines—which are also the foundation of the SSPs—provide a scientific foundation to scenario choice and construction. Moreover, they also increase the transparency of the scenario process and can thereby enhance the intelligibility of scenarios for users.

Overall, the history of scenarios used by the IPCC shows multiple trade-offs between scientific credibility, public salience, and political legitimacy of scenarios (Girod et al., 2009). This can be illustrated using the two debates discussed above. First, the progressive exclusion of business-as-usual, but also of explicit policy intervention scenarios increased the political legitimacy of the scenario process, because the United States and developing countries had expressed their opposition to the inclusion of both types of scenarios (albeit for different reasons). However, by excluding explicit policy choices and thereby the possibility of evaluating the effect of contrasting policy and governance options, this development also tended to reduce the public salience of scenarios. Second, the inclusion of storylines and multiple baseline scenarios in the SRES and the current SSP-RCP methodologies was seen as a way to enhance the scientific credibility of scenario construction. This came at the price of reducing public salience, because the high number of baseline scenarios and an increasingly unclear classification makes it difficult for wider publics to understand the political assumptions underlying IPCC scenarios and the reasons behind the wide range of warming outcomes.

3.2

The scenario framework of this Outlook

3.2.1 SSP high-priority scenarios

The five high-priority SSP scenarios (O'Neill et al., 2016; Meinshausen et al., 2020) make a suitable basis for the *Outlook*, because these scenarios represent a wide range of socioeconomic narratives and emissions pathways, but are nevertheless limited in number, increasing their salience. The limited scenario selection is generic enough to withstand a multidisciplinary assessment of plausibility, which may be unable to distinguish between small differences between scenarios. The high-priority scenarios were also selected in such a way as to maximize usefulness to multiple research communities (Gidden et al., 2019). Finally, the selection encompasses a forcing level corresponding to the 1.5°C-warming target and therefore maintains political legitimacy.

3.2.2 Very low emissions, the 1.5°C-target, and deep decarbonization

Scenario SSP1-1.9 is the only high-priority SSP scenario that is designed to constrain warming within 1.5°C by the end of the century (O'Neill et al., 2016; van Vuuren et al., 2017; Meinshausen et al., 2020). A related set of four scenarios in the *IPCC Special Report on Global Warming of 1.5° (SR1.5)*, Scenarios P1-P4, were also specifically designed to comply with the 1.5°C-target and illustrate how different balances between emissions reductions and carbon dioxide removal (CDR) could meet this target (IPCC, 2018b). All scenarios that meet the 1.5°C-target reach net CO₂ emissions around the year 2050 (Rogelj et al., 2018).

The SSP1 narrative is ill-suited for the social-plausibility assessment in Chapter 5, since its techno-economic focus omits descriptions of deeper social processes that create the motivation for such a socio-economic future. We therefore propose the scenario description *deep decarbonization by 2050* (see Section 3.4), which complements the techno-economic assessment in Section 3.3 and frames the most critical aspects for assessing the social plausibility of the low emissions scenario.

For the physical plausibility assessment in Chapter 6, we return to SSP1-1.9 for calculating long-term warming. Since the 1.5°C-target and deep decarbonization by 2050 are approximately commensurate with the greenhouse gas concen-

trations described in SSP1-1.9, both the techno-economic (Section 3.3) and social plausibility (Chapter 5) assessments can be brought to bear on this scenario and help limit the range of scenarios in the physical science framework.

3.2.3 Very high emissions

For the techno-economic assessment in this chapter, we examine the high-priority emissions scenario with the highest emissions, SSP5-8.5. In the physical plausibility assessment in Chapter 6, we then draw upon the results of the techno-economic plausibility assessment for very high emissions.

3.3

Plausibility of existing scenarios

None of the scenarios mentioned in Sections 3.1 and 3.2 were developed with a probabilistic interpretation in mind. About twenty years ago, some discussion emerged on whether scenarios should be given a probabilistic interpretation or not (Grubler and Nakicenovic, 2001; Schneider, 2001; Schneider, 2002). Currently, the “not”-camp prevails. Nakicenovic et al. (2014) gave no probabilistic interpretation when the SPA/SSP-framework was introduced, and the later accounts and applications followed suit (e.g., O’Neill et al., 2016; Riahi et al., 2017). The question is whether there is sufficient information for providing some sort of probabilistic weighting on scenarios (Ho et al., 2019; Hausfather and Peters, 2020). We claim that such probabilistic information would be valuable in two ways. First, the range of plausible mitigation costs could be constrained. Mitigation costs are derived from contrasting a no-mitigation policy scenario (baseline scenario) and a scenario with the same set of assumptions but including a mitigation-policy goal. Baseline scenarios with lower emissions must close a smaller emissions gap in the mitigation policy scenario and therefore have lower mitigation costs. If the set of baseline assumptions could be constrained probabilistically, so could plausible mitigation costs. Second, the community dealing with centennial-scale adaptation planning could reduce the scope of global warming futures they accept as plausible. The first step in the *Outlook* methodology consists in a review of existing studies that influence the techno-economic plausibility of some future climate scenarios.

The IPCC SR1.5 (IPCC, 2018b) presents many scenarios compatible with the 1.5°C target, and all of them require net negative emissions at some point in time. We therefore assume that the plausibility of low emissions scenarios depends on the demand for negative emissions technologies, comprising bioenergy with carbon capture and storage (BECCS), afforestation and reforestation, direct air carbon capture and storage, enhanced weathering, ocean fertilization, biochar, and soil carbon sequestration. While limited evidence points to the possibility of complying with the 1.5°C target without dedicated negative emissions technologies (Holden et al., 2018), a majority of authors sees these technologies as necessary (Fuss et al., 2018b; Hilaire et al., 2019). SR1.5 specifies an interquartile range of 364 to 662 GtCO₂ to be removed through BECCS by 2100 (IPCC, 2018b). Concerns have been expressed regarding this scale (Boysen et al., 2017), referring to the pressure on global water use. In general, the resulting potential conflicts arising from BECCS involve fertilizer and water needs (Heck et al., 2018), competition with food production (IPCC, 2019) and biodiversity protection. Following Smith et al. (2016), the water requirements for removing one GtCO₂ with BECCS could be as high as 500 km³, or about 10 % of current annual global water demands (Boretti and Rosa, 2019). This implies substantial trade-offs between mitigation and other SDGs (see also Box 2).

We note two further mechanisms that add to the implausibility of complying with the 1.5°C target. First, its plausibility might already be hampered by the baseline assumptions (Boysen et al., 2016). Second, mitigation costs are thought to double when raising the ambition from a 2°C to a 1.5°C target (Rogelj et al., 2015).

There are also arguments that speak against the plausibility of very high emissions scenarios. Scenario RCP8.5, the forerunner of SSP5-8.5, was constructed as a high-end emission scenario and should not be understood as a business-as-usual scenario (e.g., Hausfather and Peters, 2020). But is it at least plausible? A number of arguments against its plausibility have been articulated. Ritchie and Dowlatabadi (2017) expressed doubt as to whether the recoverable coal reserves would suffice to fuel this scenario. Hausfather and Peters (2020) argued that the falling cost of clean energy sources is a trend unlikely to be reversed, making a fivefold increase in coal use by the end of the century implausible. Furthermore, Levermann (2014) and Stern (2016) hypothesized that RCP8.5

is inconsistent because warming-induced damages would dampen economic growth to such an extent that it would be unable to drive the necessary emissions. This hypothesis has received support from modeling work that incorporates feedbacks between warming, the economy, and emissions reductions. Relative to baseline scenarios such as RCP8.5, emissions were reduced by 4.7% (Roson and van der Mensbrugghe, 2012) and 14% (Woodard et al., 2019) in year 2100. This implies that baseline assumptions would have to be even more extreme than in RCP8.5 to generate the emission levels underlying this scenario. Finally, modeling work that explicitly accounts for climate-induced economic damages in a forward-looking manner results in substantially lower economically optimal twenty-first-century emissions and global warming (e.g., Hänsel et al. 2020).

In summary, there is substantial techno-economic evidence against the plausibility of both very low emissions scenarios compatible with 1.5°C climate futures and very high emissions scenarios such as RCP8.5.

3.4

Deep decarbonization by 2050

The techno-economic evidence against very low emissions scenarios speaks against the plausibility of large-scale deployment of CDR technologies. However, some very low emissions scenarios, such as P1 from the IPCC SR1.5 rely more on rapid emissions reductions than on CDR to reach net carbon zero. To complete our plausibility assessment of these very low emissions scenarios, we must therefore also consider the plausibility of rapid emissions reductions, reaching around net carbon zero by 2050 in order to meet the 1.5°C target. The plausibility of rapid emissions reductions by 2050 is inherently anchored in the plausibility of social processes, which provide the impetus to bring about such wide-reaching social change. In Chapter 4, we develop a framework to analyze the social processes that might drive such a social transformation. For this purpose, we propose a scenario that describes that social transformation—*deep decarbonization by 2050*.

Deep decarbonization describes the transition to net-zero carbon emissions, which entails very low carbon intensity in all sectors of the economy (Deep Decarbonization Pathways Project, 2015) and a reduction in energy demand and demand for carbon-intensive consumer goods (IPCC, 2018b). Such a transition also implies a radical social transformation, including changes in norms, regulations,

institutions, and individual behaviors and personal values (Shove and Walker, 2010; O’Brien, 2018). The scenario must be delineated from other, less constrained futures in which decarbonization is only partially achieved by 2050. However, the scenario must also be generic enough to allow interpretation and assessment of their social plausibility.

We therefore deliberately exclude quantitative details concerning exact emission levels and different types of forcings, and focus on the approximate magnitude of change required to bring about a net-zero balance of the sources and sinks of CO₂ on a global scale. We assume that the social transformation required to bring about net carbon zero will contain sufficient societal momentum to reduce human-induced climate forcings other than CO₂ to net zero. Similarly, the techno-economic assumptions about economic growth, population growth, and carbon prices do not form part of the scenario.

We also allow for a small CDR stopgap, based on the techno-economic analysis in this chapter. This allows us to include futures in which net zero carbon is almost reached, but in which some regional economies or sectors resist complete decarbonization by 2050, since the capability of national and regional economies to decarbonize will depend on their current energy mix and respective institutional structures (Bataille et al., 2016: 8). Providing for a

small CDR stopgap buys time or relieves part of the burden of socio-technical change for these resistant regions and sectors, and relieves the burden of attempting to forecast exact quantities of emissions by 2050, which is not tenable given the qualitative nature of the social plausibility assessment.

We delineate deep decarbonization from partial decarbonization in the extent and speed at which such transformation occurs. This distinction is necessarily qualitative, but some quantitative assessment can place the magnitude of this extent and speed in perspective. To reduce the approximately 36 GtCO₂ per year of worldwide anthropogenic CO₂ emissions (Friedlingstein et al., 2019) by around 90% decarbonization by 2050, a compounding mitigation rate (Raupach et al., 2014) of over 7% of global emissions would be required each year. This mitigation rate is equivalent to reducing year-on-year emissions every year until 2050 at the rate in reductions caused by the worldwide COVID-19 lockdown measures in 2020 (see Box 4).

Further qualities of decarbonization can place the extent and speed of such a transformation in perspective. For example, there are considerable constraints on the speed at which new zero-carbon industrial technologies will need to be developed and then deployed (Monschauer et al., 2019). The diffusion of new technologies is typically delayed by formative phases of commercial experimentation and learning, followed by optimization of design or up-scaling, which can take many decades (Wilson, 2012). There is some evidence that transitions in some markets and for some technologies are not always long, protracted affairs (Sovacool, 2016). However, even when a technology is mature enough for market penetration, there are additional delays caused by existing capital investment, which locks in particular modes of consumption (see discussion on path dependence in Chapter 4). For example, even if electric cars reach considerable technological maturity in the next decades, the lock-in effects of internal-combustion engines that have already been purchased could significantly delay decarbonization in the transport sector (Climate Transparency, 2019; Monschauer et al., 2019). We can therefore expect that the legislative and regulatory changes to promote the needed socio-technical transformation must be in place well in advance of 2050.

The nature and speed of the transition will also be determined by who drives the change. For example, decarbonization might be driven bottom-up by changes in social behavior, cultural meaning, and niche innovations that alter the existing market. Alternatively, decarbonization might be driven top-down by incumbent actors in policy and industry; in this case, practices and lifestyles may remain unchanged, but a radical technological substitution of energy sources and heavy reliance on CDR would be required. The resulting energy mix (Geels et al., 2020; Rogge et al., 2020; van Sluisveld et al., 2020) can vary dramatically, especially the relationship between solar and wind. Similarly, the reduction in energy demand, the prevalence of public transport, and the market share of battery or hybrid passenger vehicles can all depend on which strategic actors drive the change (van Sluisveld et al., 2020). Some challenges in the low-carbon transition—such as finding solutions to energy storage—will require a combination of technological, institutional, and social innovation (Eyre et al., 2018). Tracking social drivers may therefore sharpen our perspective of which actors are leading the change and sharpen our definition of the deep decarbonization scenario in future *Outlooks*.

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BOX II Synergies and trade-offs in the assessment of plausible climate futures

There is robust evidence that ambitious climate change mitigation can be in conflict with some sustainable development goals (SDGs), resulting in trade-offs, while showing potential for synergies with others (Pradhan et al., 2017; Fuso Nerini et al., 2019; Kroll et al., 2019). Scenarios that both limit global warming and exploit synergies across multiple SDGs are explored in the *IPCC Special Report on Global Warming of 1.5°C (SR1.5)* in the form of *climate-resilient development pathways* (Roy et al., 2018). The SR1.5 claims that scenarios which both limit global warming and enhance sustainability and equality (e.g., SSP1 or SR1.5 P1) in fact “show fewer mitigation and adaptation challenges and are associated with lower mitigation costs” (IPCC, 2018b). The synergies in low emissions scenarios can even outweigh the costs of mitigation. Examples of such synergies are improved air quality and human well-being. Trade-offs, however, exist between mitigation strategies and strategies for enhancing biodiversity and food security, such as in the case of large-scale employment of land-based carbon dioxide removal technologies (Rogelj et al., 2018; Karlsson et al., 2020).

With respect to the plausibility of climate futures, we argue that a scenario such as deep decarbonization becomes more plausible if we observe increasing evidence for synergies between ambitious climate action (SDG 13) and other goals, and less plausible if we observe increasing evidence for trade-offs. While the SR1.5 stresses the potential for synergies (Roy et al., 2018), recent attempts to assess the trajectory of synergies and trade-offs between SDGs (Pradhan et al., 2017), specifically between SDG 13 and other SDGs, suggest “notable trade-offs” (Kroll et al., 2019) could emerge in the future. Nevertheless, the actual manifestation of synergies and trade-offs between SDGs is highly context-specific, as are climate-resilient development pathways. Therefore, we need an approach that allows a qualitative perspective on social-ecological conditions and contexts. The following example of urban development illustrates potential trade-offs and synergies between climate change mitigation, adaptation, and human development.

Example: Trade-offs and synergies in climate-friendly urban development

Urban development is currently facing considerable challenges, including the need to transform cities toward increased mitigation and resilience (Rosenzweig et al., 2018; Chatterton, 2020). Trade-offs and conflicting goals are becoming apparent on multiple levels. A well-known example is the spatial trend toward de-concentration and suburbanization (e.g., of residents and workplaces) and the concurrent intentions to promote a compact city

based on concentration and densification (SDG 11). From the perspective of climate change adaptation, decentralized settlement structures are more resilient. Not only do they provide more green and blue spaces to counter microclimatic problems or buffer against extreme events, they also increase the capacity for self-sufficiency. The spatial distancing of decentralized structures also makes it easier to respond to crises (such as COVID-19). However, urban sprawl has been criticized for decades as it goes hand in hand with increased land use, long travel distances, higher costs for supply infrastructure, and therefore with higher greenhouse gas emissions. Denser structures, on the other hand, have advantages with respect to more efficient material and energy flows, short distances and easy accessibility, making them preferable from the perspective of climate change mitigation. At the same time, this requires external food, energy and water supply, and creates dependencies between cities and their hinterlands.

Contradictions between controversial adaptation and mitigation goals are becoming apparent. New ways of dealing with water in the city, for example, where the concept of the *sponge city* is replacing the former idea of *drying the city*, are subject to increasing competition for space (Bell et al., 2017). Adaptation interventions in favor of a sponge city will lead to additional cooling effects, and an increase in green spaces and biodiversity as rainwater and floods no longer run off quickly but are absorbed in the city. The space this requires, however, and the associated re-design of infrastructure is likely to require high investment costs. More incentives for sustainable urban lifestyles linked to walkability, bikeability, consistent reduction of waste and recycling, use of recycled water, co-managed sustainable energy supply, and local producer-consumer associations are central to the New Urban Agenda (UN, 2017). At the same time, urban real-estate price increases that result from ecological restructuring could promote the displacement of socially disadvantaged groups, and *green gentrification* has already become a new catchphrase describing ecologically oriented, but socially imbalanced urban development (Gould and Lewis, 2017).

4

The Social Plausibility Assessment Framework

- 4.1**
— Societal climate futures as a research object
- 4.2**
— An assessment framework centered on social processes

4

The Social Plausibility Assessment Framework

Debates over climate futures pose questions of structure and agency, path dependence and contingency, as well as dynamics and change, which are at the heart of social science scholarship. In this chapter, we present a Social Plausibility Assessment Framework for climate futures that attempts to overcome the dominant focus in scenario-based modeling—but also in large parts of transitions research—on techno-economic drivers of change. We do so because we believe that societal factors will constitute both the main barriers and the main drivers of low-carbon climate futures in the coming decades. We therefore propose a new perspective centered on social processes. We start by defining a specific climate future (or scenario, see Section 3.4), and a corresponding set of social drivers.

These drivers represent (emergent) social processes that are identified in relation to the scenario, because they are considered key to its realization. Each driver is in turn characterized by a historic trajectory and specific contextual conditions, which enable or constrain societal agency for change. The explicit consideration of constraining conditions breaks with the optimism bias that pervades much of existing decarbonization research. Furthermore, the analysis of resources produced by the social drivers sheds light on the constitution of the emergent *global opportunity structure* for ambitious climate mitigation. After a review of approaches of societal climate futures research (Section 4.1), we present the Social Plausibility Assessment Framework and its methodology (Section 4.2).

4.1

Societal climate futures as a research object

Societies are constituted by structures that represent sedimentations of large historical processes and institutions. They are also shaped by agency—that is, the capability of individual and collective actors to formulate future aims and realize them in the present, even if only partially and with unforeseen outcomes (following Emirbayer and Mische, 1998), in the form of everyday social practices and individual decisions (Giddens, 1984; Tilly, 1984). As a result, societal institutions, norms, and values are both stable and evolving. Any assessment of possible and plausible climate futures must therefore focus on the interplay between structure and agency (Meadowcroft, 2009; Geels, 2014). Moreover, to assess climate future scenarios, one must consider the fact that societal futures are not given, but always in the process of becoming (Polak, 1973). As a result, and given their societal embeddedness, climate futures cannot be predicted in the narrow sense of *determining in advance*, but can be explored with regards to both inertia in social processes (path dependency) and the possibility of social change, via critical junctures or path departure (Edenhofer et al., 2014; Schulz, 2015). This does not mean that we

cannot say anything about the future. It is possible to formulate informed conjectures by analyzing and evaluating past, present, and emergent social dynamics (Schwartz-Shea and Yanow, 2013). Rather than focusing on the futures as predetermined by history or as a completely open, indeterminate space of possibility, this approach emphasizes “futures in the making”, where past actions and decisions enable, structure, and delimit current actions and decisions (Adam and Groves, 2007).

Emergent dynamics of change can be generated by disruptive innovations and market dynamics, new norms and narratives, or by social mobilizations and political upheavals (Beckert, 2009; Mische, 2014). Likewise, emergent dynamics of change may result from more incremental processes of learning in organizations and communities of practice (March and Olsen, 1989; Wenger, 2010). Outcomes of previous transformations thereby alter the conditions for future changes. For example, the current dynamics and trajectories of German and French energy transitions are profoundly shaped by previous policies and social mobilizations on coal and nuclear energy, respectively (Aykut and Evrard, 2017).

On the one hand, discourses and narratives are constitutive for social structures and (soft) institutions such as norms, rules and principles, and belief-systems (Somers, 1992; Doty, 1997; Milliken, 1999; Wiener, 2006). On the other hand, societal engagement with and contestations of contemporary issues generate novel narratives and frames, thereby changing the very conditions for change to occur (Jenson, 1993; Tarrow, 1993). This particularly applies to issues such as climate change, which are characterized by complexity and uncertainty due to rapid environmental change and potentially disruptive societal transformations (Chaffin et al., 2014; Beck, 2016). To assess the social plausibility of climate futures, we therefore must go beyond a singular focus on path dependency and socio-technical structures, but we must equally avoid an overstatement of the potential for quick transformative change. Such a perspective is particularly helpful for identifying possibilities for societal intervention without reducing social dynamics to mechanical cause-effect relationships. With these elements in mind, we propose an approach that allows us to both account for social inertia and to observe change while it is happening.

4.1.1 Existing approaches: techno-economic models, socio-technical transitions, social tipping points

Recent developments in transitions research have significantly broadened the scope of analytical tools available to assess climate futures. New approaches have complemented the dominant focus on techno-economic model simulations. Among these new approaches, some center on socio-technical scenarios and the feasibility of transition pathways, others on social tipping points and levers for societal transformation. Taken together, these perspectives have considerably enriched research on climate futures. But some important blind spots remain. These relate in particular to the status of history, the role of societal agency, and a bias toward enablers at the expense of obstacles to low-carbon climate futures. In this section, we discuss these perspectives and show where our approach builds on them, and where it departs from them.

Scenario-driven modeling is widely used in global environmental governance to assess uncertainties and inform policy-makers and wider publics. This also applies to the climate literature. IPCC assessments have long relied on scenarios from the SRES family and SSP-RCP matrix (see Chapter 3). However, model and scenario development for climate assessments mostly involves scholars from economics, engineering and the natural sciences (Cointe et al., 2019; van Beek et al., 2020). Social science knowledge is traditionally sidelined, or only used to derive exogenous trends or qualitative storylines (Pulver and Vandever, 2009). Such frameworks therefore neglect non-economic processes and societal agency in shaping transition pathways

(Hofman et al., 2004). Drawing on innovation studies and sociology of technology, scholars have recently proposed to bridge model-based and qualitative approaches through a focus on socio-technical scenarios (Geels et al., 2016; Turnheim and Nykvist, 2019; Hof et al., 2020). Such bridging attempts have mostly, though not exclusively, adopted the analytical lens of the multi-level perspective (MLP) in socio-technical transition analysis. This perspective conceives sustainability transitions as “innovation journeys”, in which the successful scaling up of niche innovations unsettles established socio-technical regimes (Schot and Geels, 2008).

Compared to techno-economic models, a socio-technical perspective foregrounds the importance of user practices, actor-coalitions and regulatory environments. It thereby enables researchers to qualify and evaluate the social and political feasibility of transition pathways (Turnheim and Nykvist, 2019; Geels et al., 2020). However, transition studies arguably still place their primary analytical focus on technological innovation as the main driver of social change. This insufficiently captures the role of power and politics in shaping low-carbon transitions (Stirling, 2014). Moreover, the focus on niches appears out of touch with the current phase of the energy transition. With cheap technological alternatives already available in a range of sectors, the new frontier for deep decarbonization is social and political (National Academies of Sciences, Engineering, and Medicine, 2021: 1). Accelerating the coal phase-out, for example, is primarily a problem of creating the social, political, and regulatory environment necessary to decommission large amounts of installed coal capacity (Chattopadhyay et al., 2021). Another strand of the literature has centered on social tipping points and levers for societal transformations. Social tipping points refer to elements in socio-ecological systems whose activation would trigger non-linear changes and lead to a qualitatively different state of the social system (Milkoreit et al., 2018: 23). For example, Otto et al. (2020: 2356) identify six social tipping elements—within energy production and storage, human settlements, financial markets, norms and value systems, education, and information feedbacks—as candidates with the greatest potential for initiating rapid change. Similarly, research on sustainability transitions has identified overarching levers (or strategic actions) and leverage points (or priority points for intervention) for societal transformations (Chan et al., 2020).

The approaches mentioned above constitute important inspirations for the Social Plausibility Assessment Framework. However, they also entail a series of blind spots. First, techno-economic and systemic approaches neglect history as a key analytic problem. To a lesser degree, this also applies to studies on socio-technical transitions, when these studies underestimate the extent to which deep societal transformations inevitably also transform identities, social agents, institutions, structures, and even causal mechanisms (Beck, 2016; O'Brien,

2018). Second, most transition research struggles to properly account for societal agency in change processes. In taking policies, innovations, or social tipping interventions as analytic starting points, studies fail to explain why and how—through which social mechanisms or forces—governments or other societal actors feel compelled to engage in bold climate action in the first place (Smith et al., 2020). Third, the prevailing focus on—often decontextualized—enablers, tipping points, or levers neglects context-specific constraints to change (Geels et al., 2020) and entails the risk of mistaking desirability for feasibility (Jewell and Cherp, 2019). Our approach addresses these blind spots by placing a unique focus on social processes, their enabling and constraining conditions, and how these processes and conditions change over time. In line with the central guiding question of CLICCS, we develop analytical tools that permit assessing if, in the light of past and emergent dynamics and changing context conditions, a particular climate future appears plausible or not. Rather than focusing on what should happen to make a scenario plausible (normative approach), we systematically explore the social plausibility of climate futures (analytical approach).

4.1.2 A new perspective centered on social processes

Our framework complements existing approaches in transition research by foregrounding social processes as the drivers that condition the social plausibility of climate futures. The framework is based on a selection of key drivers and a comparative assessment of their dynamic effect. This places the focus not only on historic trajectories and legacies, but also on societal agency and context-specific enabling or constraining conditions for transformations. We understand social processes as temporal phenomena of a certain duration, which develop a dynamic momentum of their own (Stinchcombe, 1964: 103). They are constituted by, but also constitutive of, social agents, institutions, and mechanisms, and they are embedded in specific structural and institutional environments that constrain or enable them (McAdam et al., 2003; Tilly, 2008). The notion is thereby positioned against evolutionary approaches (because history matters), structuralist approaches (because agency matters), and purely variables-based approaches (because context matters). It draws attention instead to processes of inertia and change within given social contexts.

History matters: Transitions are neither deterministic, nor entirely contingent on their trajectories. When assessing climate futures, it is therefore necessary to turn to routinized practices and institutions, as preconditions for future developments. Path dependence thereby points to a range of social mechanisms that cause inertia, such as positive feedbacks, network externalities, increasing returns in economic markets and technologies (Arthur,

1989), social institutions and organizations (Beyer, 2010), slack and political processes (Pierson, 1996), and discourses (Jenson and Mérand, 2010). However, social change is neither impossible in principle nor inevitable after a certain threshold (as the tipping-point metaphor suggests). For new paths to stabilize, they require continuous societal interventions and political support (Hall and Taylor, 1996), and new shifts may occur when power structures and political alliances change (Hess, 2014).

Agency matters: Transitions are, to a large degree, initiated, supported, and accelerated by societal agents such as social movements, NGOs, or associations (Ciplet et al., 2015; de Coninck et al., 2018: 352). Hence, while recent studies rightly stress the importance of policies in driving technologies and markets (Cherp et al., 2018), a process-perspective holds that social transformations do not begin with, but rather result in, government interventions (Smith et al., 2020). Moreover, a potentially disruptive event, societal intervention, or political decision can have very different effects at different moments in a social sequence (Bonoli, 2007). It may constitute a “critical juncture”, when uncertainty of institutional arrangements is high (Capoccia and Kelemen, 2007). The potential for path departure may be increased by “critical situations”, such as psychological or social changes that unsettle institutionalized routines (Giddens, 1984: 61), or “windows of opportunity” in policy processes (Kingdon, 1984).

Context matters: The importance of contextual boundary conditions for societal transformations has received particular attention with protest and social movement research (Kitschelt, 1986; McAdam et al., 2003). Such contextual conditions, which can be political, discursive, normative or economic, are specific to the societal agents or social processes under consideration (Jenson, 1993: 339). This usefully complements discussions on opportunities and obstacles, or enabling conditions and constraints, of sustainability transformations (de Coninck et al., 2018).

For the purposes of our assessment framework, we situate drivers and identify comparatively stable context conditions to assess their dynamic effect toward or away from a specific climate future. Taken together, these studies of driver dynamics (history) and their enabling and constraining conditions (context) also offer a novel take on change (agency), by unveiling the contours of a *global opportunity structure* for societal agency toward specific climate futures. By *global opportunity structure* we mean the global “repertoire” (Tilly, 2006) of resources generated by the different social processes, which acquire global visibility and can be used by societal agents in national and transnational contexts. Such resources include climate treaties, activist networks, landmark cases of climate litigation, new policy instruments, energy discourses, and climate-related norms. The global opportunity structure frames the political, economic, legal, and cultural context of transnational societal agency in relation to a given scenario.

4.2

An assessment framework centered on social processes

The Social Plausibility Assessment Framework places the analytical focus on (emergent) social processes that drive social dynamics toward or away from a specific climate future. Our approach selects relevant drivers in relation to a predefined future scenario and in doing so departs from established forecasting approaches, which ask where an extrapolation of current developments would lead us. We thereby also include emergent processes that might otherwise have been overlooked. The framework also differs from pure backcasting approaches, which aim to describe the necessary developments to reach a given future scenario. The framework thereby allows an attention to history and social inertia to be combined with an interest for agency and emergent dynamics of change.

The Social Plausibility Assessment Framework builds on the characterization of a specific future scenario. We then identify a series of key drivers, which matter for the realization of this particular long-term future. In the next step, we single out specific enabling and constraining conditions for these drivers. Scenarios and drivers, as well as drivers and their enabling and constraining conditions, are closely linked. Together, they provide the basis for assessing the social plausibility of the scenario. We do so by extrapolating current driver trends, as well as by identifying driver interactions, key resources, and constraints for societal agency to move toward the scenario. This space of resources and constraints that have global relevance and visibility creates, for instance, a global opportunity structure for sustainable climate futures. Whether or not the global opportunity structure works effectively toward a given scenario depends on whether and how the resources it comprises are used by a plurality of societal agents. Only when these resources are widely used by societal agents do the resources obtain global materiality.

The Social Plausibility Assessment Framework allows us to combine and articulate a multitude of disciplinary approaches and methods. The following presents the main concepts of the framework in more detail.

4.2.1 Main concepts and theoretical underpinnings

Future scenarios

The Social Plausibility Assessment Framework tests the plausibility of a scenario, which is the description of a climate future (see Figure 2). This description should be specific enough to be testable but

not too specific or techno-economic-focused as to undermine a comprehensive assessment of social drivers. In climate policy debates, scenarios are usually based on an internally consistent set of assumptions about key driving forces and relationships between variables, but also entail some combination of qualitative narratives (mostly about future socio-political trends) and quantitative modeling (mostly about biophysical and economic processes). For the purpose of this *Outlook*, we focus primarily on qualitative techno-economic and social characteristics of a specific social climate future (Section 3.4).

The relevance of a scenario rests on its ability to provide a narrative that reduces social complexity by offering a mutually intelligible story (Rouse, 1996; Bueger and Gadinger, 2018: 135). They provide an “intelligible account that captures the play’s plot” (Hansen-Magnusson, 2020: 48). As interpretive devices, narratives provide orientation, and as such they are helpful for recognizing real-world change and making it visible for societal agents (Della Sala, 2018). Similarly, scenarios produce stories about potential evolutions of the world, and thereby constitute problems for acting in the present (Mallard and Lakoff, 2011). They are the product of, and embedded in, practices of policy-framing, knowledge production, deliberation, or contestation (Tully, 2002; Forst, 2010; Wiener, 2018b). Scenarios have therefore come to form part of a wider set of “anticipatory knowledge practices” (Aykut et al., 2019), which shape the ways in which problems in climate debates are identified, and in which solutions are framed and implemented (Beck and Mahony, 2017).

Social drivers

Each future scenario is characterized by specific social features, some of which differ significantly from the present. We therefore need to understand which social processes are key drivers that affect the relevant social dynamics toward or away from these scenario-features. However, in the existing literature, the notion of drivers is commonly used to designate techno-economic variables that trigger low carbon innovations and market dynamics (Marcucci and Fragkos, 2015), or to designate macro-variables such as population, consumption and technological development that correlate with emissions growth (Rosa et al., 2015), or determinants of climate-related decisions of individuals and policy-makers (Edenhofer et al., 2014).

Therefore, while existing definitions tend to relate drivers to techno-economic variables, societal macro-indicators, individual action, or policy-making, we understand drivers more broadly as overarching social processes that generate change toward or away from a given scenario and its characteristics. As social processes, drivers mediate between societal agency and social structure (Elias, 1978). They span micro, meso, and macro scales of global society (Jordan et al., 2018) and generate “climatizing” effects by diffusing climate concerns in new governance arenas and societal domains (Aykut et al., 2017). Drivers thereby reflect societal multiplicity and the agency of a plurality of stakeholders (Rosenberg, 2016), but also reflect dynamics in economic markets and sociotechnical regimes (Geels et al., 2017), and in social movements and conflicts (Tormos-Aponte and García-López, 2018). Given the intrinsic complexity of social reality, the list of drivers is potentially endless and their identification therefore, at least partly, an analytical choice (Geels et al., 2020).

Enabling and constraining conditions

Existing research has identified a wide variety of general enabling conditions for climate mitigation, such as the alignment of financial flows, technological innovations, policy instruments and interventions, institutional capacity, global governance, and changes in human behavior, norms, and lifestyles (de Coninck et al., 2018; O’Brien, 2018; Shukla et al., 2020). Comparative studies on sustainability transitions have also focused on identifying a series of transition potentials (Turnheim and Nykvist, 2019) and bottlenecks (Geels et al., 2020).

By contrast, enabling and constraining conditions in our framework need to be further specified with regards to specific drivers. According to our societal perspective on climate futures, we propose a more detailed and systematic view of enabling and constraining conditions, which relates them to the contextual boundary conditions of drivers as social processes. Enabling and constraining conditions describe those driver-specific institutional, structural, and material environments which favor

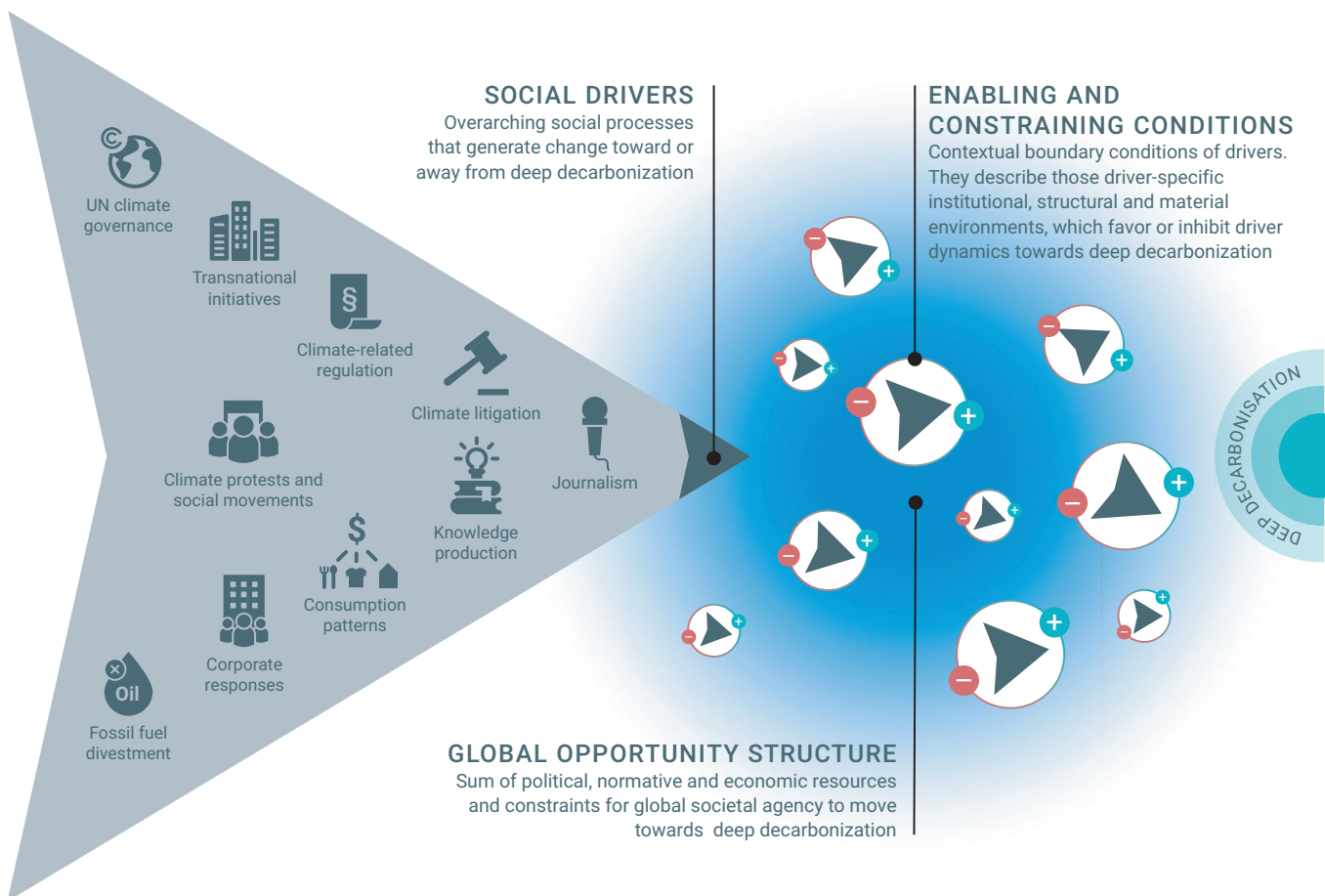


Figure 2: Components of the Social Plausibility Assessment Framework. The figure shows the chosen climate future scenario, deep decarbonization (right), and the selected key social drivers of deep decarbonization (left; see Chapters 5 and 8 for a description and analysis of the drivers). The assessment of the driver dynamic (center), their enabling and constraining conditions, and the potential global opportunity structure leads to a conjecture about the plausibility of the future scenario (Section 5.3).

or inhibit driver dynamics toward a specific climate future. The research therefore targets drivers and their dynamics in relation to enabling and constraining conditions, and with a view to obtain a better understanding of the emergent global opportunity structure.

Global opportunity structure

The current struggle to mitigate climate change is driven by a diverse range of actors including protest movements, firms, organizations, and transnational litigation networks. This sheer diversity transcends familiar descriptions by global governance approaches. We argue that this wide range of societal agency is a key indicator of the potential for change toward sustainable climate futures. Since the social drivers' respective agents operate across micro, meso, and macro scales of global order, they are simultaneously constitutive for an emerging and essential set of resources for societal transformation. Societal agency is thus central for establishing the visibility and subsequently the materiality of these resources.

The notion of *opportunity structure* originates in social movement research, where it designates a repertoire of resources generated and used by political agents in national and transnational contexts. Opportunity structures comprise "specific configurations of resources, institutional arrangements and historical precedents" (Kitschelt, 1986: 58). Opportunity structures are therefore a context-sensitive analytical tool (Koopmans, 1999: 102) that enables researchers to identify, for example, political, economic, legal, cultural, and normative conditions that enable or constrain the dynamics of social processes. The effect of the opportunity structure increases with the materiality of its resources.

By analogy, and reflecting the globalized quality of climate policy, we argue that even though political opportunity structures are specific to a particular social and political context, they are also evolving through processes of transnational and inter-societal interaction. We can therefore speak of a *global* opportunity structure (see Figure 3), which represents the repertoire of resources and constraints for global societal agency to move toward a specific climate future. Although constructed through local activities and struggles, this repertoire is of global relevance when its resources are visible and obtain a material quality that makes them accessible to be used by protagonists of climate struggles worldwide. Since drivers are social processes that are moved along by societal agency, they generate resources through interaction. Their visibility is constituted, for example, by documents, media reports, and through communication. Once these resources are used by other agents around the globe, they acquire a degree of materiality which turns them into enabling (or constraining) elements of the global opportunity structure. The driver assessments in Chapter 5 of this *Outlook* document resources, their global visibility, and potential impact on change toward the deep decarbonization scenario (identified in Section 3.4). Their materiality and effect as resources of the global opportunity structure remain to be detailed by studying their use.

GLOBAL OPPORTUNITY STRUCTURE

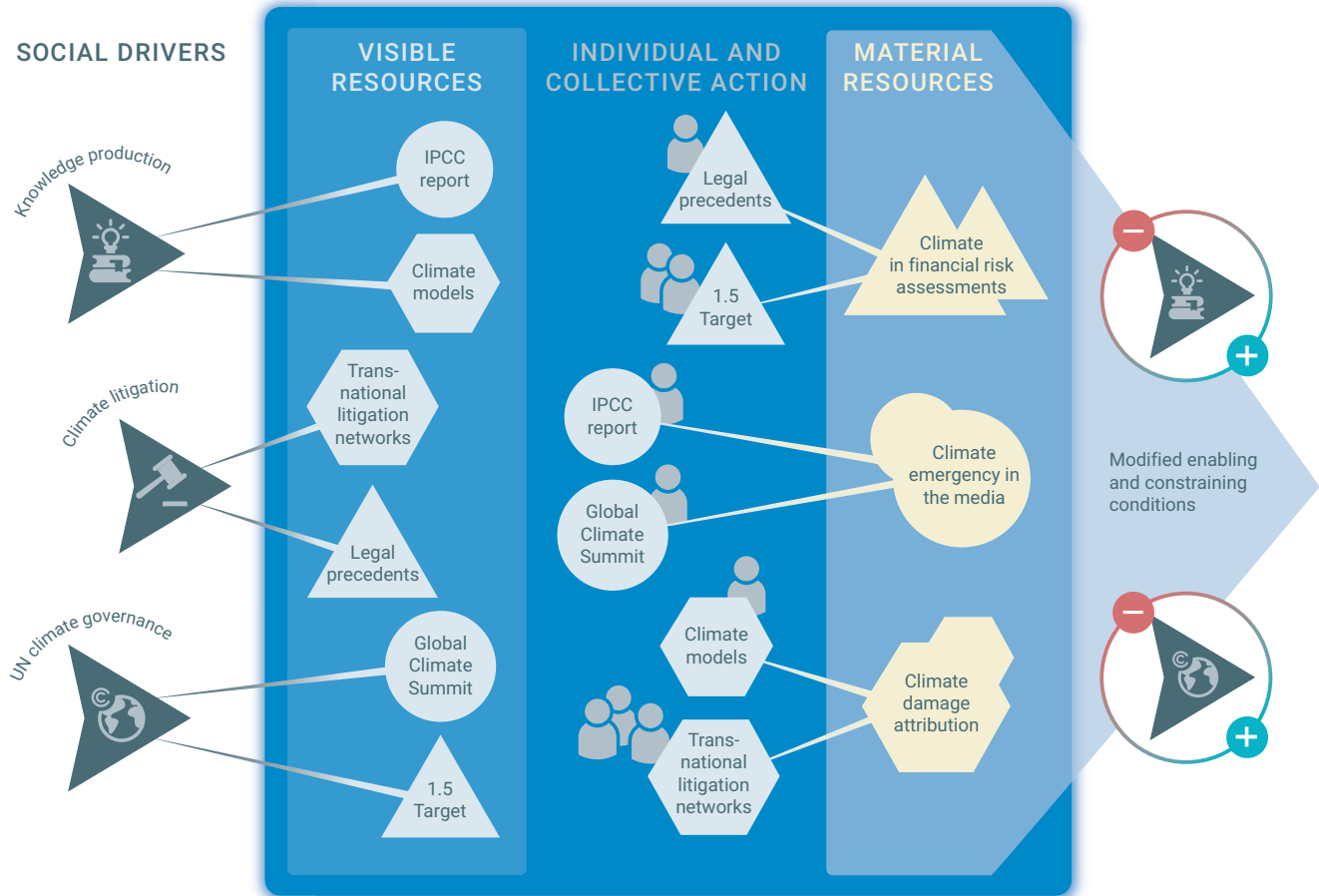


Figure 3: The global opportunity structure. Social drivers (left) provide resources that become more material as they move from left to right in the figure. If the resources become visible to societal agents on a global level (center), these agents can use and combine them in material ways, which can influence driver-specific environments and therefore the enabling and constraining conditions of other drivers (right).

4.2.2 Assessment methodology

The Social Plausibility Assessment Framework is designed to frame the research operationalization following the research question: Which social dynamics work toward or away from a specific climate future? The research objective of the first *Hamburg Climate Futures Outlook* consists in identifying drivers and their dynamics with regard to achieving deep decarbonization by 2050.

Working with the Framework implies the following four steps (see Figure 2):

1. Defining the scenario and describing its key characteristics (we define the scenario of deep decarbonization by 2050, see Section 3.4)
2. Identifying a selection of key social drivers that represent relevant ongoing and emergent dynamics toward that scenario (see Section 5.1)
3. Assessing the past and emergent driver dynamics (Section 5.2 and Chapter 8)
 - ▶ If the drivers continue their current trajectory, will they support social dynamics toward a given scenario?
 - ▶ Do currently observable enabling or constraining conditions support respective driver dynamics toward that scenario?
 - ▶ If not, are there signs that the direction of drivers is or will be changing?
 - ▶ Under which conditions (e.g., changes in enabling conditions, interaction with other drivers) could such a change be expected?
 - ▶ Does the driver provide global resources that are visible and accessible to other societal actors or drivers, and how are these resources changing or showing signs of changing?
4. Synthesizing the individual driver assessments to an overall evaluation of the scenario's plausibility (Section 5.3)
 - ▶ Evaluating the overall scenario plausibility based on the synthesis of respective driver dynamics
 - ▶ Describing the emerging global opportunity structure as a potential repertoire of resources generated by the different drivers and their interaction.

As we demonstrate, social drivers, their dynamics, and their contextual conditions are key empirical resources for assessing future scenarios. Given that the form and effect of drivers are not fixed but contingent, drivers—and the direction of their dynamic—must be identified in a given context. It then becomes possible to undertake informed conjectures with regard to the plausibility of future scenarios. Accordingly, qualitative or quantitative information that is obtained by observing socioeconomic systems and sociopolitical processes generates key indicators which speak in favor or against the plausibility of a particular scenario. The spectrum of evidence includes detailed information about drivers, their past and current trajectory, enabling and constraining conditions, and dynamic interaction.

According to the framework outlined above, the empirical research focuses on social drivers, and what their dynamics indicate about the projected scenario. Working with the Social Plausibility Assessment Framework implies that we would expect a given climate future (e.g., deep decarbonization) to be plausible if individual driver dynamics or changes in their enabling conditions generate strong momentum for change (this may involve windows of opportunity, path departure, novel resources or repertoires within the opportunity structure, and/or external disruptions). The needed momentum may also arise if drivers reinforce one another, such as when some drivers create favorable enabling conditions for others. The focus on enabling and constraining conditions, driver interactions, and the global opportunity structure is therefore designed to avoid a mere extrapolation of current trends and instead to open a space of social plausibility. The approach can thereby also inform discussions on potentials for political intervention or societal agency.

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Assessing the plausibility of deep decarbonization by 2050

- 5.1**
— Identifying the social drivers of decarbonization
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- BOX III**
— Diverse ways of knowing in a changing climate

5

Assessing the plausibility of deep decarbonization by 2050

This chapter presents an analysis of the social drivers and dynamics that influence the pathways toward or away from the scenario *deep decarbonization by 2050* (see Section 3.4). Section 5.1 introduces the social drivers of decarbonization considered in this assessment. Section 5.2 then presents the guiding questions and a summary of the social driver assessments, based on the in-depth assessments presented in Chapter 8. Section 5.3 synthesizes the social driver dynamics toward or away from deep decarbonization by 2050 and addresses the impli-

cations of the empirical findings for the plausibility of very low emissions scenarios, such as SSP1-1.9. We conclude that reaching deep decarbonization by 2050 is currently not plausible. However, the social driver assessments indicate the plausibility of partial decarbonization by 2050. Our synthesis also points to a series of resources produced by the social drivers that could be utilized by societal actors to bring about a change in direction toward deep decarbonization.

5.1

Identifying the social drivers of decarbonization

The social drivers of decarbonization selected for this assessment were developed by building on expertise within the CLICCS Cluster of Excellence and on existing literature on social transformation for deep decarbonization. The CLICCS researchers who developed the drivers come from a wide range of disciplines—including sociology, political science, law, communication studies, geography, and economics—and applied an inductive approach to identify key drivers of decarbonization from within their disciplinary contexts. Through expert elicitation among different CLICCS working groups and a series of internal workshops, the group refined the set of drivers and defined the scope of analysis that is both necessary and feasible for a first meaningful analysis of their dynamics with respect to the scenario of deep decarbonization by 2050.

The social drivers addressed in this *Outlook* correspond in part to social tipping interventions that are considered necessary for reaching deep decarbonization by 2050, such as climate policy enforcement and financial market investments (Otto et al., 2020). However, our driver assessment is unique in that it draws on a conceptual understanding not only of the social driver dynamics, but also their enabling and constraining conditions (see Section 4.2.1). The selected drivers also address key social dynamics described in the IPCC SR1.5, which include multilevel governance, institutional

capacities, lifestyle and behavior, and climate finance (de Coninck et al., 2018). Although technology, also mentioned in de Coninck et al. (2018), is a critical driver for deep decarbonization and might be explored in future editions of the *Outlook*, in this first issue, we explicitly focus on the missing social dynamics that go beyond technology-centric approaches (Ehrhardt-Martinez et al., 2015; see Box 1).

As explained in Section 4.1, our Social Plausibility Assessment Framework foregrounds social processes as drivers, so that we consider not only climate policy and regulation, but also deeper social dynamics that allow political legitimation to arise in the first place (Messner, 2015; Nikas et al., 2020) and that “facilitate or constrain practical responses to climate change” (O’Brien, 2018: 156). In particular, our methodology focuses on historic trajectories and legacies, societal agency, and context-specific enabling or constraining conditions for transformations toward or away from specific scenarios.

The ten selected social drivers span various levels of social dynamics across different scales and levels of governance, including trans- and subnational processes. The drivers UN climate governance (Section 5.2.1), transnational initiatives (Section 5.2.2), and climate-related regulation (Section 5.2.3) provide frameworks and laws within which state and non-state actors can coordinate their response to climate change mitigation. Climate protests and

social movements (Section 5.2.4) create pressure for policy-makers and other powerful actors to act, share public narratives, and provide the background for political legitimation to ambitious climate action. Climate litigation (Section 5.2.5) uses law and legal mechanisms to enforce or prevent stronger climate action. Corporate responses to climate change influence industrial emissions and the carbon intensity of consumer choices (Section 5.2.6), while fossil fuel divestment (Section 5.2.7) critically affects the long-term viability of carbon engagements. Consumption patterns is a demand-side driver that has direct effects on global emissions (Section 5.2.8).





Finally, we assess the role of journalism (Section 5.2.9) and knowledge production (Section 5.2.10), which provide fundamental underpinnings of societal transformations by influencing the flow of information and meaning, but whose effect on deep decarbonization is especially difficult to assess.

To assess the plausibility of deep decarbonization by 2050, we do not analyze each social driver in every specific national context. We rather perform a global assessment, which covers the most relevant and observable worldwide trends that are critical for each social driver of decarbonization and the plausibility of the scenario.





5.2

Summary of the social driver assessments

The following ten social driver assessments summarize the in-depth assessment of social plausibility in Part II of the Outlook (Chapter 8), and are structured along *five guiding questions* that are key for concluding how their dynamics affect the plausibility of deep decarbonization by 2050, drawing on the Social Plausibility Assessment Framework (see Section 4.2.2):

- ▶ If the driver continues its current trajectory, will it support or undermine social dynamics toward deep decarbonization?
-  Do currently observable enabling or constraining conditions support or undermine driver dynamics toward deep decarbonization?
-  Are there signs that the direction of this driver is or will be changing?
-  Under which conditions (e.g., changes in enabling conditions, interaction with other drivers) could a change in direction toward deep decarbonization be expected?
-  Does the driver provide global resources that are visible and accessible to other societal actors or drivers, and how are these resources changing or showing signs of changing?

The answers to these questions deliver empirical evidence about the current dynamics of the driver and its enabling and constraining conditions. This evidence is synthesized in a driver-specific plausibility assessment, which evaluates whether the driver dynamics and conditions:

-  Are sufficient for deep decarbonization by 2050
-  Support decarbonization, but are not sufficient for deep decarbonization by 2050
-  Do not inhibit decarbonization, but it is unclear if they are sufficient for deep decarbonization by 2050
-  Inhibit decarbonization


The short summaries of the driver assessments are followed by a synthesis including the overall plausibility assessment of the scenario (Section 5.3).

5.2.1 UN climate governance


Supports decarbonization, insufficient for deep decarbonization by 2050


UN climate governance, as we understand it here, comprises state-led cooperation within the UN Framework Convention on Climate Change (UNFCCC) and the wider climate change regime complex.

▶ Despite a poor historic track record, UN climate governance gained new momentum since the adoption of the Paris Agreement in 2015. The Paris Agreement is the first universal climate agreement with a quantified, indirectly actionable target (“well below 2°C”). It aims at aligning expectations and policies on that target through a bottom-up approach of pledge and review, transparent reporting, polycentric governance, and discursive work. However, operationalization and implementation of the Paris Agreement are not on track with deep decarbonization. Central operational aspects are still being negotiated, countries’ National Determined Contributions (NDCs) are not aligned with the temperature target, and their implementation is not on track. Moreover, a severe shortcoming of the Paris regime is that key issues of finance, trade, aviation, and maritime transport are so far insufficiently regulated.

 The current geopolitical, societal, and economic context is arguably more favorable for achieving decarbonization than ever before, but some key obstacles remain. Global youth protests and conducive national policy environments in major countries (the European Union, China, and recently the United States) put climate on the global political agenda. Discernible changes in business practices, the availability of low-carbon technologies, and a discursive shift from negative impacts to economic opportunities of decarbonization have favorably altered the incentive structure for global cooperation. However, continued fossil fuel dependence of key countries, industries, and modes of transportation create powerful path dependencies that prevent deep decarbonization, while the risk of authoritarian populist movements and persistent institutional fragmentation in international regulation threaten to undermine the regime.

▶ There is first evidence for a race to the top as envisaged by the Paris Agreement approach, as a growing number of countries and companies submit net-zero carbon emissions pledges. Combined with the return of the United States to the Paris Agreement, this opens a window of opportunity for UN climate governance to support deep decarbonization in the near future. However, since the implementation of net-zero pledges is subject to ongoing political disputes, a clear assessment is difficult at this point.

 A change in direction can only be expected if a new wave of climate protests after the COVID-19 pandemic continues to put pressure on governments, and ambitious climate-related regulations create trust and momentum by aligning NDC implementation and COVID-19 recovery plans with Paris Agreement objectives. This could be supported by effective transnational initiatives that enable sectorial low-carbon transformations and build support for deep decarbonization. Moreover, new knowledge about climate risks or green technologies can attract media attention and clarify solution spaces.

 UN summits regularly provide media attention and leverage for climate movements, scheduling and agenda-setting effects for climate-related regulation, and networking opportunities for transnational initiatives, notably through the Marrakesh Partnership for Global Climate Action. Recent COPs (Conferences of the Parties) have also guided the production of scientific reports (e.g., on global warming of 1.5°C) and provided journalists with resources to build narratives around low-carbon successes and climate emergency. Finally, the Paris Agreement constitutes a source of (legal) norms invoked in national debates and in climate litigation cases against governments and companies.

5.2.2 Transnational initiatives

Supports decarbonization, insufficient for deep decarbonization by 2050

Transnational initiatives refer to new forms of climate governance that cut across traditional state-based jurisdictions and operate across public and private divides. They encompass a wide variety of voluntary climate actions taken by subnational authorities, private businesses, civil society actors, and research institutions, which intend to coordinate across borders and produce collective effects to mitigate climate change.

▶ The last decades saw an increase and diversification of transnational initiatives, as well as a surge in the engagement of non-state actors in climate governance. New ambitious initiatives are regularly announced during UN summits and COPs, supporting net-zero pledges. These initiatives potentially constitute a driver for deep decarbonization that is complementary to state actions (such as NDCs), although the actual contribution to fill the emissions gap is yet to be seen. While performance has improved over the past decades, an assessment of the effectiveness of transnational initiatives is difficult, due to the lack of common accounting, monitoring, and reporting frameworks.



The post-Paris architecture of climate governance creates an unprecedented opportunity for transnational initiatives to share best practices, publicize actions, formulate needs and influence policy, even if they lack funding and global assessment structures. Institutional mechanisms such as the Non-state Actor Zone for Climate Action (NAZCA) are established in the UNFCCC process to enable coordination between state and non-state actors. However, considering that most growth in greenhouse gas emissions is expected in developing or emerging countries, their participation in transnational initiatives is insufficient. There are also strong regulatory barriers to transnational initiatives, including fragmented carbon pricing, lack of policy incentives, and lack of competencies of non-state actors over their emissions scopes.



Transnational initiatives in support of deep decarbonization are increasingly deployed in various sectors (such as energy, industries, agriculture, and finance) although their potential has not been fully established. With climate governance entering implementation, more resources in transnational initiatives may be devoted to plan and operationalize commitments, reinforce accounting, and to develop common monitoring, reporting, and verification procedures.



More ambitious national-level regulation would strengthen the mitigation potential of transnational initiatives. Efforts to align finance flows with the Paris Agreement's goals would also reinforce the implementation of non-state actors and help them to secure additional funding. Finally, further net-zero pledges combined with the establishment of transparency, monitoring, accounting, and reporting obligations would enhance the accountability of non-state actors' commitments and further align transnational initiatives with deep decarbonization pathways.



Transnational initiatives build narratives on the desirability and opportunities of decarbonization, which incentivize policy-makers, investors, businesses, and cities to act. Their increasing involvement across scales catalyzes state-level ambition and action. Finally, by sharing expertise, policy recommendations, and best practices, transnational initiatives are a valuable source of knowledge production and government regulation. Examples are carbon market standards, corporate decarbonization strategies, accounting and reporting methods, and capacity-building and training.

5.2.3 Climate-related regulation



Supports decarbonization, insufficient for deep decarbonization by 2050

Climate-related regulation refers to legislation and regulation issued by national and supra-national government bodies. It intends to limit or reduce the concentration of greenhouse gases in the atmosphere, either by limiting greenhouse gas emissions or by withdrawing greenhouse gases from the atmosphere. The regulator can choose from a variety of instruments such as command-and-control instruments, market-based instruments, planning, consent-based instruments or informational instruments. Jointly they create the bounds for legal operations and the incentive structure for companies, households, and other actors.

The assessment of this driver has two components: first, to assess whether the targets are consistent with deep decarbonization and second, to assess whether the set of instruments employed will plausibly achieve these targets. Both components need to consider interactions between targets, instruments, and other drivers, as they can only unfold in this wider social context. The following is based on a cursory assessment of the situations in China, the United States, and India, and a more in-depth analysis of the European Union and Germany. Together they comprise almost half of current global greenhouse gas emissions.




On its current trajectory, climate regulation in these countries is not sufficient to support deep decarbonization. Our assessment therefore concludes that achieving deep decarbonization by 2050 is not plausible.




In recent years active public support for ambitious climate policy has been voiced prominently in several countries which has put increasing pressure on governments. While it has helped to raise ambitions and to update climate policy, it is not yet sufficient for deep decarbonization.



The COVID-19 pandemic's long-term impacts on climate-related regulation are still unclear. The recent elections in the United States and the stepping-up of ambitions in China and the European Union indicate that drivers toward deep decarbonization might gain momentum over the next five years. However, it remains to be seen whether ambitions translate into effective and coherent regulatory frameworks.

 Sufficient political support and further technological progress are crucial for the implementation of climate regulation consistent with deep decarbonization. The processes behind the formation of political support will differ substantially across jurisdictions, but climate protests and social movements, UN climate governance, climate litigation, and knowledge production are likely to be highly relevant for the implementation of climate-related regulation.


 Regulatory innovations are discussed internationally and sometimes diffuse outward to other states or can be upscaled to higher levels of governance. The German Energy Transition acts simultaneously as a litmus test and potential role model for such an ambitious transition. The perceptions of its performance shape the evolution of climate-related regulation in other countries.


5.2.4 Climate protests and social movements


Does not inhibit decarbonization, unclear if sufficient for deep decarbonization by 2050


Climate protests and social movements refers to climate-related political activism and grassroots mobilization that contribute to the public climate change discourse. Actors involved in climate protests and social movements publicly draw attention to different courses of climate action and non-action, which can provoke individual and collective decision-making around consumption, investment and abatement choices, technology adoption, voter preferences, or public policy. Therefore, this driver helps shape the speed and direction of change relative to the deep decarbonization scenario.

► Climate protests and related social movements have gained significant momentum in recent years and, by early 2020, became a key player in the climate-related political process. The COVID-19 pandemic and its repercussions over the past year have led to a major decline in both the extent of climate activism and the demand for climate-related discourse. The pandemic contributes to the already existing global inequalities created by climate change. The already limited resources and opportunities for climate activism in the Global South are further undermined through political, social, and economic constraints due to the COVID-19 pandemic. The disruption caused by the pandemic makes assessing the current trajectory of the driver highly speculative, so that at least another year of research would be required to assess pandemic-related dynamics.

 A key enabler continues to be digital communication technology, since it simplifies the exchange of information and collective action mobilization, which is nevertheless undermined by authoritarian dynamics seeking to control communication. While the shifting public attention toward challenges related to the COVID-19 pandemic undermined climate action, some activists have successfully framed the pandemic and climate change as interrelated crises. Social movements highlight climate-related knowledge production in order to gain legitimacy and call for urgent changes of existing policies. Hence, a growing public support for evidence-based regulative policies tends to further underpin the claims of climate protests.

 Just as the current direction of the driver is difficult to assess, so is its future trajectory. It is plausible that the momentum will return to pre-pandemic levels soon, but it is also plausible that the pandemic will hamper activism dynamics for a long time to come.

 Activism needs to regain attention by policy-makers and in the public sphere, in order to shift the discourse away from short-term concerns toward long-term changes required for deep decarbonization. Furthermore, climate activism needs to maintain its relations with many other social drivers of decarbonization in order to succeed under the current circumstances. For example, climate activists will need to continue to strengthen links with scientific communities in order to further advance knowledge production, and will need to continue to participate in strategic litigation.


 Climate protests and social movements occupy a central position in many national and international climate debates. In particular, the driver provides ideas, norms, and visions. These can trigger (dis-)identification and the re-interpretations of meaning for societal discourses (political, media, cultural) and for individual lifestyle choices. Simulation and appropriation practices provide infrastructure, such as local production networks and chances for identification. Through the communication of action and protest, the driver generates media attention, has an influence on setting the public agenda and creates public pressure through campaigning. This public pressure encourages firms or public institutes to divest from fossil fuels. In the past, environmental movements have often developed into more organized forms of civil society such as NGOs, which are consulted as experts for specific knowledge. In the case of climate litigation, specialized climate NGOs are providing legal advice.


5.2.5 Climate litigation


Supports decarbonization, insufficient for deep decarbonization by 2050


Climate litigation refers to lawsuits intended to drive decarbonization and climate justice. It comprises lawsuits against governments, administrations, or companies to strengthen national emissions reduction commitments, prevent carbon-intensive infrastructure projects, or hold firms accountable for warming impacts. Climate litigation may affect greenhouse gas emissions reductions in many ways, including creating pressure for more stringent regulations, enforcing international, supranational and national climate law, blocking the construction of fossil fuel infrastructure, increasing media attention for the climate cause, and producing narratives of responsibility and urgency.

▶ Assessing the impact of climate litigation is a highly complex task which requires spatio-temporally detailed analysis. Based on current research results at this stage of the inquiry, we can therefore only offer interim conclusions. For example, if the driver continues to follow the current trajectory, it is plausible that climate litigation will further increase spread geographically, and therefore have the potential to support social dynamics toward deep decarbonization. However, this development is unlikely to succeed in isolation, because it depends on the respective dynamics of other closely related drivers such as climate protests and social movements, journalism, and knowledge production.

 Key observable enabling conditions in support of this driver's dynamics toward deep decarbonization include a growing body of national and supranational climate legislation, the transnational circulation of legal know-how, the expansion of strategic litigation networks, growing scientific evidence about climate impacts and their respective attribution, and a growing transnational social movement for climate justice. However, constraining conditions such as societal backlash have materialized, for example, in the United States.

 At this stage of our analysis, we did not observe signs that the driver is changing. Notably, the COVID-19 pandemic has limited both the enabling conditions of climate protest as well as potential anti-climate policy protests. The societal backlash in the United States cemented the conservative majority in the US Supreme Court, which is expected to contravene future climate litigation cases in the United States. However, this constraining situation is likely to be countered, if not fully overcome, with the recent change to the Biden administration.

 Conditions which could accelerate changes toward deep decarbonization include new landmark rulings in favor of climate protection (e.g., company liability, change in burden of proof), significant advances in attribution science, and changes in the legal framework that grant broader access to courts.


 Climate litigation as a social process is a transnational phenomenon. Among the global resources generated by this driver, three stand out: legal precedence (case law), network capacities (litigation networks spanning micro, meso, and macro scales, which facilitates hybrid knowledge production and circulation), and agenda-setting (facilitated by media coverage).

5.2.6 Corporate responses

Inhibits decarbonization

Corporate responses include strategic positions and related activities ranging from indifferent to proactive. Exemplary activities include target setting, reporting, energy efficiency, process improvements, product innovation, carbon offsetting, and establishing low-carbon supply chains. Corporate responses could potentially lead to deep decarbonization if companies were able to combine substantial target setting with process improvements and product innovations, with the goal to significantly reduce greenhouse gas emissions. However, this would require far-reaching collective efforts in many high-emitting industries, which appears to be not plausible at present. Additionally, the vast majority of companies still engage only in low to moderate climate efforts.

▶ If the driver continues its current trajectory, empirical evidence suggests that corporate responses will not necessarily support social dynamics toward deep decarbonization. While some corporate practices are promising, further acceleration is needed in the coming years.

 Although enabling conditions exist, including climate policies (e.g., the EU Emissions Trading System) and private financial investments, they are not far-reaching and will likely shift over time, creating regulatory uncertainty and inefficient financial incentives for significant corporate responses. Beyond policies however, both sustainable investments and divestment provide an impetus toward deep decarbonization. This can level the playing field, encouraging radical innovation while introducing economic penalties for the pervasive business-as-usual paradigm. Nevertheless, the market-dominant logic of economic growth, coupled with short-term profit maximization, is entrenched in existing institutional frameworks (macro) as well as managers' cognition (micro). Even exemplary companies rarely make strong moves

toward decarbonization, because the market-dominant logic creates tensions between economic and environmental goals.

Since the current market-dominant logic—the most serious constraining condition of this driver—does not show signs of changing, there are few indications, if any, that the driver will change direction.

Thus, the corporate responses driver will likely continue on its projected course unless carbon mitigation efforts become profitable through governmental policies (e.g., carbon pricing), financial investments, and cost-effective technological replacements (e.g., fuel cells). Stringent climate policies—especially a significant carbon pricing—could stimulate a change in direction of the driver.

Corporate responses do provide global resources accessible to other drivers and actors, especially when cost-effective technologies and successful activities lead to supportive climate-related regulations and financial investments. They may also encourage social movements and shifts in consumption patterns, which could further accelerate deep decarbonization.

5.2.7 Fossil fuel divestment

Supports decarbonization, insufficient for deep decarbonization by 2050

Fossil fuel divestment is the process through which financial flows are retracted from fossil fuel exploitation. It comprises any reduction or cessation of investment or financial support for upstream (extraction) or downstream (e.g., energy provision) fossil fuel activities, and a shift in business priorities from fossil fuels to non-fossil fuels. Financial flows come from private and public sources and in the form of capital investments or subsidies. The flows are formed at global, national and subnational levels. It is currently impossible to generate a complete overview of global financial flows. This driver assessment is therefore based on a conceptual approximation, selective data sources and a literature review.

Financial flows continue to support upstream and downstream fossil fuel activities. Divestment as a social movement by political protest groups, institutional investors, and some state regulators is gaining traction, but has not reached a critical mass yet. Extraction plans for fossil fuel reserves still find sufficient financing, and many countries still depend on incomes from fossil fuel exploitation.

Three enabling conditions support fossil fuel divestment. First, a growing social movement puts political pressure on institutional investors to divest. The movement is growing around the world, and an increasing number of institutional investors have followed their call. Second, sustainability reporting standards are developed that provide transparency about fossil-fuel-related risks of investments. Third, a growing number of institutional investors are developing the expectation that fossil fuel investments will become stranded assets. However, we also find three constraining conditions. First, most countries lack regulation that would discourage investments in fossil fuel sectors. Second, capital markets are highly efficient markets that react to changes in split seconds. If one investor sells stocks of fossil-fuel-based firms, another investor will step in. As a consequence, divestment does not yet have lasting effects on the cost of capital of firms. A divestment in that sense does not reduce carbon emissions in the short term. Third, liquid equity capital markets are just one channel for financial flows, and even if the cost of capital for fossil fuel engagements rises, alternative channels are still available to finance fossil fuel industries.

A key sign of a changing direction would be the stabilization of a long-term expectation that fossil fuel investments will actually turn into stranded assets within the next two decades, not only among publicly visible institutional investors such as pension funds and insurance companies, but also among other private investors and among states dependent on fossil-fuel-based income. So far, we do not observe this sign, and countries' planned fossil fuel production and global production levels are not consistent with a deep decarbonization scenario.

The direction of the driver strongly depends on the continued or discontinued profitability of investments in fossil fuel activities. A strong decline of profitability would come from the implementation of an effective carbon price. Regulation of financial markets can have direct effects on the profitability. UN climate governance and transnational initiatives can explore alternatives to the existing carbon entanglements of nation states. These enabling conditions become more likely as worldwide political pressure increases.


Pressure from the fossil fuel divestment movement and new rules about sustainability reporting standards increase the visibility of continued financing of fossil fuel activities. This is a resource for increasingly directing political and regulatory frameworks toward decarbonization.

5.2.8 Consumption patterns

Inhibits decarbonization


Consumption patterns refer to patterns of expenditure across or within categories of products and services and are characterized by extreme inequalities. Household consumption contributes to more than 60 percent of global greenhouse gas emissions and wealthier countries generate the most emissions per capita. Transformations in the current high-emissions sectors depend on infrastructural conditions. The way in which the current patterns of consumption and production evolves has important spillover effects on decarbonization and other climate-related goals.

▶ The current trajectory of worldwide consumption patterns, if continued, will substantially undermine the social dynamics toward deep decarbonization. The limited effects of incipient changes toward sustainable consumption patterns might be largely absorbed by the continued growth in the demand and production of new perceived needs, and new goods and services.

 There is no empirical evidence pointing to fundamental changes in the current, carbon-intensive consumption patterns around the world. The institutional conditions that sustain unsustainable mass consumerism remain intact. Moreover, the currently observable enabling conditions for low-carbon consumption—in particular, climate-related regulation—still do not support achievement of deep decarbonization by 2050.

▶ Despite unprecedented levels of energy-demand decline and renewables growth, driven by the worldwide responses to the COVID-19 pandemic, recent studies reveal that rebound effects in energy consumption, fossil fuel energy production, and transport-related oil use are already in force or are likely to occur. In addition, the increasing efforts to promote sustainable consumption (e.g., sustainability- and eco-labels) lead at best to a *green consumerism* and still do not support structural transformations toward low-carbon consumption patterns. As the dynamics of food consumption show, it is not the patterns but rather the means by which people consume that might continue to change.

▶ Structural changes that might shift the ongoing dynamics of consumption patterns involve synergies between the production of climate change knowledge and the implementation of climate-related laws, regulations, and infrastructures. Science-based post-crisis recovery plans, for instance, advocate for investments and structural reforms that enable deep decarbonization. In particular, the enactment of climate-friendly laws, regulations, and infrastructures, as well as societal pressure for ambitious climate action can potentially change the current and extremely unequal patterns of consumption worldwide.


 The dynamics of consumption patterns provide other drivers such as knowledge production, climate-related regulation, and corporate responses with valuable insights into societal willingness and ability to consume specific (e.g., low-carbon) goods and services, or to reduce consumption. In particular, the future dynamics of this driver will reveal changes in socioeconomic factors as well as social interactions, norms, and practices that fundamentally influence the pathways toward or away from deep decarbonization.

5.2.9 Journalism


Does not inhibit decarbonization, unclear if sufficient for deep decarbonization by 2050


Journalism includes journalistic coverage, provided on a multitude of offline and online channels and is a relevant source of information on climate change for large parts of the public. Communication research has highlighted the potential correlations between journalistic media coverage on climate change and perceptions, attitudes, and behaviors of audiences—even though the media’s impact is mediated by the characteristics of the respective audience.


▶ We observe dynamics in journalism that could support deep decarbonization, such as the increasing media attention to climate change, a trend away from the kind of balanced reporting that led to an over-representation of climate change denial, and a framing of the issue as a more concrete political, cultural, and individual topic. We expect that the key drivers of media reporting will continue to push climate change on the media agenda and thus also shape the broader public agenda. Nevertheless, journalism interacts with other sources of information and does not have universal, linear effects on all population segments. Therefore, although we expect the increasing trend in reporting around climate change to help drive deep decarbonization, this may not be the case for all social groups.

 While some enabling conditions—such as engagement of individual journalists, new types of reporting, and editorial processes—support driver dynamics toward deep decarbonization, there are multiple constraining conditions. These include journalistic norms and values, including the need to focus on events for reporting on long-term processes like climate change, the fact that the news factors of conflict and negativity provide news value, and continued visibility for climate change denial. In addition, media environments have become contested terrains due to the rise of “alternative” channels on the internet, including social media, which open new arenas for conspiracy narratives and the spread of misinformation around climate change. Communication on such channels

often mimics journalism but is not effectively regulated; no professional gatekeepers are involved and thus no journalistic norms apply. Both enabling and constraining conditions, including the precarious financing of journalism, have created a situation in which the future impact of journalism on a deep decarbonization trajectory is fundamentally open.

 The direction of the driver is currently changing, but so are its enabling and constraining conditions. Therefore, although the driver will likely continue to influence climate futures as a key information source for many parts of the public, its impact for the specific scenario of deep decarbonization is currently impossible to assess.


 Journalism could drive significant momentum toward deep decarbonization if there is an ongoing media attention to climate change, if journalism continues to produce evidence-based, motivating, and engaging reporting that is tailored to specific audiences, and if journalism's financial future is secured by new sources of funding.


 Journalism is a driver that interacts with all other social drivers in making content visible and accessible; its main resource is attention, devoted to certain problems and actors. As such, journalism does not determine the other drivers but can rather enhance already existing social dynamics. Its role in shaping the agenda should therefore not be underestimated.


5.2.10 Knowledge production


Supports decarbonization, insufficient for deep decarbonization by 2050

Knowledge production refers to practices of knowledge generation and validation that provide facilitative capacities for envisioning and enacting transformations toward deep decarbonization. In order to retrace the trajectory of the driver and mindful of diverse ways of knowing (see Box 3), we distinguish between stages in which different types of knowledge—background, scientific, and packaged—come to fruition. This assessment will focus on packaged knowledge, such as IPCC assessments, as the most material type of knowledge production that is tailored to align with specific political processes and policy-making.

 Currently, we observe a significant rise in packaging practices in contexts beyond the IPCC (e.g., UNEP Emissions Gap Report, World Energy Outlook, Climate Action Tracker). Each is aimed at different political and societal groups, and their function consists in identifying possible and plausible climate futures, and creating legitimacy for the social implementation of corresponding transformation processes. In combination with a continuation of recent developments toward a more solution-oriented IPCC process, these growing packaging practices have the potential to provide important resources for societal dynamics toward deep decarbonization.

 Due to the increasing institutionalized role of packaged knowledge, we observe progressive alignment of knowledge production with political processes. This has the potential to enhance the impact of packaged knowledge in public policy and in societal discourse on deep decarbonization. Beyond the positive effect of packaged knowledge on deep decarbonization, our research on the stages of knowledge production highlights two developments. First, constraining conditions for this driver include the lack of empirical data regarding the effect of diverse ways of knowing, and second, enabling conditions include a growing interest in research programs and institutions that address ethnic diversity and societal multiplicity.

 To date, there is no sign that the relevance of knowledge production and its use will decrease. However, this cannot be taken for granted. Current practices of packaging knowledge for the adoption policies toward deep decarbonization could fall victim to their own success if they interfere with existing lifestyles (i.e., via a concrete restrictive effect of regulatory policies).

 Given the fact that knowledge production is a cross-cutting driver, the driver has the potential to develop dynamics toward deep decarbonization due to its relation to all other drivers. It becomes more central in packaged forms in various contexts, such as in climate-related regulations and in learning from diverse ways of knowing.

 At this early research stage our research identified an enhanced global visibility of packaged knowledge as a vital resource of climate policy-making. With regard to indicators of change, two leading questions highlight what we consider central issues of global contestation. First, what is considered to be *best available science*? Second, whose knowledge counts as scientific? Both questions require further empirical research given their importance for societal transformations toward decarbonization.

5.3

Plausibility assessment of the scenario and its implications

By synthesizing the driver assessments, the following sections present the plausibility assessment of the deep decarbonization scenario (Section 5.3.1), discuss its implications for the plausibility of the very low emissions scenario SSP1-1.9 (Section 5.3.2), and summarize the conditions and resources for future change toward deep decarbonization (Section 5.3.3).

5.3.1 The plausibility of deep decarbonization by 2050

Based on the observed past and emergent dynamics, none of the ten social drivers assessed in the Outlook are sufficient to effect deep decarbonization by 2050. Six drivers—climate litigation, climate-related regulation, knowledge production, transnational initiatives, UN climate governance and fossil fuel divestment—have dynamics that we evaluate as supporting decarbonization. However, there is also evidence of substantial opposing dynamics within each driver. Therefore, these six drivers do not currently sufficiently support the transformations necessary to reach the scenario. Two drivers—consumption patterns and corporate responses—have overall dynamics that inhibit further decarbonization. The potential of two social drivers to support decarbonization is currently impossible to assess; these are climate protests and social movements, due to the disruptions caused by the COVID-19 pandemic, and journalism, due to interactions with other sources of information.

There are currently no observable dominant enabling conditions that indicate a plausible change of driver trajectories toward deep decarbonization by 2050. In most cases, there are signs of enabling conditions that would support social driver dynamics toward decarbonization. However, there is also evidence of significant constraining conditions for each driver. For example, the availability of low-carbon technologies and a discursive shift from the negative impacts to the economic opportunities of decarbonization would enable UN climate governance to support deep decarbonization. Furthermore, other conditions constrain this driver, including continued fossil fuel dependence of key countries, industries, and modes of transportation, risk of authoritarian populist movements, and persistent institutional fragmentation in international regulation. We observed digital communication technology and strong public support as enabling conditions for social movements and climate protests, but authoritarian and popu-

list governments prevent this driver from creating pressure to adopt ambitious climate policies. In the case of corporate responses, the market-dominant logic is a constraining condition that prevents a change toward deep decarbonization.

We conclude that reaching deep decarbonization by 2050 is currently not plausible. The current dynamics of key social drivers of decarbonization and of their enabling conditions are insufficient to bring about the rapid, wide-ranging social transformations needed to achieve deep decarbonization by 2050 (as described in Section 3.4). However, since several drivers and enabling conditions indicate some movement toward further climate action, there is evidence that a partial decarbonization remains plausible. Whether these dynamics can develop into a trajectory that supports deep decarbonization depends on the exploitation of resources that help create the necessary conditions for such a change.

5.3.2 Implications for the plausibility of the SSP1-1.9 scenario

Our analysis of the social drivers of decarbonization indicates tendencies that run counter to the assumptions of very low emissions scenarios (cf. Section 3.2.2). We find arguments against the plausibility of the SSP1 scenario family and therefore the baseline scenario, and against the high-priority scenario SSP1-1.9, which implements mitigation measures that decrease emissions below the SSP1 baseline.

Societal boundary conditions of the SSP1 scenario family include (1) global cooperation: increasingly effective and persistent cooperation across governance levels; (2) public policy: investments and reform of tax structures leading to improved energy efficiency and switch to renewables; (3) economy: *green growth* and *green economy* replace dependence on fossil fuels; (4) lifestyles: consumption oriented to less resource-intensive lifestyles, away from fossil fuels and toward a low-meat, plant-based diet (O'Neill et al., 2017).

However, many aspects of our social driver assessment speak against the plausibility of the SSP1 baseline assumptions. The assessment of UN climate governance indicates the rise of illiberal and authoritarian populism worldwide and the inefficiency of the current assessment practice, which runs counter to the assumption of strong cooperation in SSP1. Continued fossil fuel investments outweigh declared divestments, while companies overwhelmingly continue on a trajectory of business-as-usual

in the absence of strict climate-related regulations, which speaks against the assumptions of *green growth* and *green economy* in SSP1. Climate-related regulation also indicates limited progress; although climate objectives became more ambitious in some parts of the world in 2019 and 2020, the implementation of these objectives is lacking. Finally, consumption patterns do not currently support a shift to less resource-intensive lifestyles.

We furthermore find evidence that speaks against the mitigation measures required for the high-priority scenario SSP1-1.9, in order to bring its emissions below the SSP1 baseline. SSP1-1.9 requires strong emissions-reduction measures to achieve deep decarbonization by 2050, which we find to be currently not plausible in our assessment in Section 5.3.1. The deployment of CDR technologies can alleviate some of the burden of emissions reductions, but we find evidence speaking against a large-scale deployment of CDR in the techno-economic assessment (Section 3.3). We therefore conclude that SSP1-1.9 and other comparable very low emissions scenarios are currently not plausible.

5.3.3 Conditions and resources for future change

Although reaching deep decarbonization by 2050 is currently not plausible, there is empirical evidence about the potential for future changes that could make this scenario plausible. The social plausibility assessment sheds light on a series of resources generated by the respective social drivers of decarbonization, which might impact the enabling conditions for deep decarbonization. For example, UN climate governance and transnational initiatives provide societal agents with important networking spaces for knowledge production, political agreements, and norms for climate regulation. The same is true for climate litigation, climate protests and social movements, and journalism, which also pave the way for a wider societal mobilization for climate action. In turn, innovative climate-related regulations and corporate responses might produce spillover effects, by providing incentives for the diffusion of further low-carbon regulatory and corporate initiatives.

The wide range of resources produced, and the wide range of societal agents involved in climate mitigation efforts (e.g., governments, scientists, social movements) point to the constitution of a *global opportunity structure* (see Section 4.2.1) for ambitious climate action. This global opportunity structure, if utilized, has the potential to support structural transformation toward deep decarbonization. While it is not yet possible to say whether these or other resources will fundamentally change the current dynamics of social drivers, there are four main conditions that would shift those dynamics and make the scenario of deep decarbonization by 2050 plausible. First, ambitious climate change mitigation depends on political momentum for climate action. That is, increasing societal support and political impetus for climate action are important driving forces for deep decarbonization. Second, the successful implementation and worldwide diffusion of climate-friendly laws, policies, and infrastructures are key to ambitious climate mitigation. Such implementation and diffusion processes depend on a third condition—the combination of societal pressure with the systematic inclusion of climate mitigation measures in the political agenda of national and subnational governments. Finally, the first three conditions are expected to support fossil fuel divestments and the leverage of financial resources for climate mitigation, which has great potential to shift the current dynamics of social drivers toward deep decarbonization.

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Box 3: **Jan Petzold, Antje Wiener**, Martina Neuburger, Jan Wilkens, Alvine Datchoua-Tirvaudey, Michael Schnegg, Dirk Notz, Eduardo Gresse, Jürgen Scheffran, Jana Lüdemann, Tobias Schmitt, Katrin Singer

BOX III Diverse ways of knowing in a changing climate

Knowledge and knowledge production affect the way people perceive and engage with the world. *Diverse ways of knowing* refers to diverse scientific or everyday practices and technologies for accessing the world, including different approaches within the same epistemic system, such as observations and models, and different epistemic systems, such as local, traditional, or indigenous knowledge systems (Crate et al., 2019; Schnegg, 2019; Singer, 2020). There is robust evidence that diverse ways of knowing matter for climate change mitigation (Brugnach et al., 2014), adaptation (Petzold et al., 2020), and sustainable development in general (Sterling et al., 2020).

With respect to assessing plausible climate futures, engaging with diverse ways of knowing is important in various ways. It is important, for example, to help explain social and behavioral change or inertia due to diverse interpretations of global warming (O'Reilly et al., 2020), to help identify trade-offs with sustainable development that are expressed through the contestation of global norms on local sites (Wiener, 2018b), and to help advance knowledge co-production approaches in support of climate observation, climate projections, and resilience and adaptation strategies at the local and regional scale (Forbes, 2011; Balbo et al., 2016; Savo et al., 2016). This inclusive approach facilitates a better understanding of different types and stages of knowledge production and their impact on policy decisions (see Section 8.10). The following examples demonstrate how CLICCS researchers engage with diverse ways of knowing and how they matter for assessing and interpreting plausible climate futures.

Through cross-cultural comparison of “different ways of explaining climate change”, Schnegg et al. (2021) demonstrate that people often combine different epistemologies. For example, scientists and laypeople often agree that humans are the cause of global warming. But the scientific and local understandings of how local practices and climate change interact can also diverge (Brüggemann and Rödder, 2020). Furthermore, some indigenous communities blame themselves for climate change, since in their ontologies, the weather is perceived as a local phenomenon, which rewards and punishes people for their right and wrong actions (Rudiak-Gould, 2014; Schnegg et al., 2021). These findings urge us to rethink how different understandings of the environment and climatic changes influence people's behavior, and how this relates to our expectations of plausible social dynamics, for example, regarding consumption patterns (Section 8.8) or social movements and climate protests (Section 8.4).

Climate justice is a key contested norm of global climate governance, which includes diverse approaches from the Global South (Sovacool et al., 2017). Climate justice has diverse “meanings-in-use” contingent upon how it is enacted (Wiener, 2009) by societal agents across spatial and temporal contexts. Wilkens and Datchoua-Tirvaudey (2020) explore these meanings by zooming in on sites of contestation in the Arctic and the Mediterranean, and studying affected stakeholders' justice claims. They argue that a decolonial approach is particularly helpful to account for multiple diversities (i.e., justice claims, scale, and ways of knowing). The researchers identify distinct expectations of societal agents toward climate change policies, and identify practices of contention that allow further research to assess whether or not support exists for goals that are set by global climate regimes. The study also accounts for diverse epistemologies and ontologies of nature and climate. This becomes visible in many climate governance issues such as the discussions around trade-offs between climate action and sustainable development (see Box 2).

Diverse ways of knowing also help understand how likely changes in the natural system might be. One example for such a diverse approach relates to new ways to integrate insights from both observations and models to project plausible futures of our climate system. For example, Notz and Stroeve (2018) combine insights from observations, conceptual modeling and large-scale numerical models to obtain a more robust understanding of future changes in Arctic sea-ice area than would be possible by just one of these approaches.

In conclusion, integrative assessments such as the *Hamburg Climate Futures Outlook* benefit from the engagement with diverse ways of knowing by incorporating fundamental aspects of social-ecological dynamics that affect climate futures. In this edition, the social drivers knowledge production (Section 8.10) and climate litigation (Section 8.5) show that engaging with diverse ways of knowing is relevant for assessing the plausibility of deep decarbonization by 2050.

Which temperature trends can we expect for the 21st century?

- 6.1**
— Climate sensitivity and global mean surface temperature
- 6.2**
— When would we see the effect of emissions reductions in global temperature?
- 6.3**
— Regional temperature trends and their uncertainty
- BOX IV**
— COVID-19 and the changing climate

6

Which temperature trends can we expect for the 21st century?

The plausibility of climate futures is inextricably linked with the plausibility of future trends in surface warming, since both global and local trends in surface temperature are key indicators of climate change and its impacts. Current practice so far, including in IPCC reports, has made every statement of temperature trends contingent on the assumption of a particular emissions scenario. Since the plausibility of the scenario itself is not assessed, the overall plausibility of a deduced temperature trend cannot be assessed either. We help to close this existing research gap with our assessment in Chapter 6. We build on the results of the preceding techno-economic and social plausibility assessments and discuss the implications for the physical plausibility of climate futures, in particular the

expected warming by the end of the twenty-first century. Section 6.1 combines the new insights from the techno-economic and social plausibility assessments (Chapters 3 and 5) with recent advances in estimating climate sensitivity to suggest upper and lower limits to plausible global surface warming by the year 2100. Section 6.2 investigates a related problem: If partial decarbonization is indeed plausible, as Chapters 3 and 5 suggest, when will we be able to detect the effectiveness of the required mitigation measures? Section 6.3 turns to the regional level, exploring the impacts of plausible global temperature rise on the variability of summer temperatures in Europe; this variability poses substantial challenges for regional adaptation.

6.1

Climate sensitivity and global mean surface temperature

If deep decarbonization by 2050 is implausible, what can be said about the plausibility of long-term global surface warming ranges? The two key concepts required to answer this question are radiative forcing and climate sensitivity. *Radiative forcing* tells us how much energy is trapped in the climate system when the atmospheric composition changes, in particular when increased greenhouse gas concentrations enhance the human-induced greenhouse effect. *Climate sensitivity* tells us how much the surface temperature changes in response to a given magnitude of radiative forcing.

The emissions scenarios from the SSP families describe not only socio-economic assumptions (see Section 3.1) but also how strongly the climate is perturbed, which is characterized by the radiative forcing in the year 2100. In a nomenclature such as SSP1-2.6, the first number describes the broad socio-economic assumption (here, SSP1 refers to a world of sustainability and equality, see Section 3.1), whereas the second number indicates a radiative forcing of approximately 2.6 Wm^{-2} by the year 2100.

The scenario framework in the *Outlook* follows the five high-priority SSP scenarios (Section 3.2).

The techno-economic and social plausibility assessments in the preceding chapters produce evidence against the very high and very low emissions scenarios. The very high emissions scenario SSP5-8.5 implies a combination of underlying assumptions and economic consequences from climate change that we characterize as implausible. The very low emissions scenario SSP1-1.9 becomes implausible due to the combined techno-economic and social assessments. Extensive reliance on carbon dioxide removal to compensate emissions is not plausible, which implies that the SSP1-1.9 scenario relies on deep decarbonization by 2050. However, the direction of the social drivers does not currently support the plausibility of deep decarbonization by 2050. Following our assessment, the scenarios with plausible forcing are therefore represented by the remaining high-priority scenarios SSP1-2.6, SSP2-4.5, and SSP3-7.0. Note that in this first *Outlook*, we are not yet able to assess the plausibility of these remaining scenarios, and so we assume that the three remaining scenarios are plausible.

The surface warming in response to the radiative forcing is most prominently characterized by the

equilibrium climate sensitivity (ECS), the long-term globally averaged surface warming following a doubling of the atmospheric CO₂ concentration. For decades, the uncertainty range of ECS has stubbornly resisted reduction; in the last IPCC Assessment Report (AR5), ECS was assessed to lie between 1.5°C and 4.5°C, with a probability of 66% or higher that the true value lies within this range (Collins et al., 2013).

A second measure of sensitivity is the transient climate response (TCR), which marks the global surface warming by the time of doubling of the CO₂ concentrations in an idealized scenario, in which CO₂ concentrations increase by 1% per year; doubling occurs after 70 years. In the AR5, the 66% uncertainty range was assessed to be 1.5°C–2.5°C (Collins et al., 2013). Note that TCR is always smaller than ECS because TCR characterizes an incomplete warming response to a CO₂ doubling.

Several of the newest generation of comprehensive climate models have placed ECS substantially above the old uncertainty range; three models have ECS higher than 5°C (e.g., Forster et al., 2019; Zelinka et al., 2020). While the higher-ECS models been argued to provide more accurate representations of

extra-tropical clouds than previous models (Zelinka et al., 2020), the very sensitive models substantially overestimate the global surface warming over the past several decades and are hence unlikely to provide a faithful representation of future warming (Jiménez-de-la-Cuesta and Mauritsen, 2019; Brunner et al., 2020; Liang et al., 2020; Nijse et al., 2020; Tokarska et al., 2020).

Recent comprehensive evidence from feedback process understanding, the observed historical climate record, and paleo-climate records has substantially reduced the ECS uncertainty range (Sherwood et al., 2020). The 66% range has been assessed as 2.6°C–3.9°C, about half the range assessed by the IPCC AR5, and even their 90% range is at 2.3°C–4.7°C narrower than the AR5 66% range. This new ECS uncertainty range by Sherwood et al. (2020) confirms the assessment that the most sensitive comprehensive climate models overestimate global surface warming (Jiménez-de-la-Cuesta and Mauritsen, 2019; Brunner et al., 2020; Liang et al., 2020; Nijse et al., 2020; Tokarska et al., 2020).

We now determine new plausible warming limits by taking the following steps. We use the

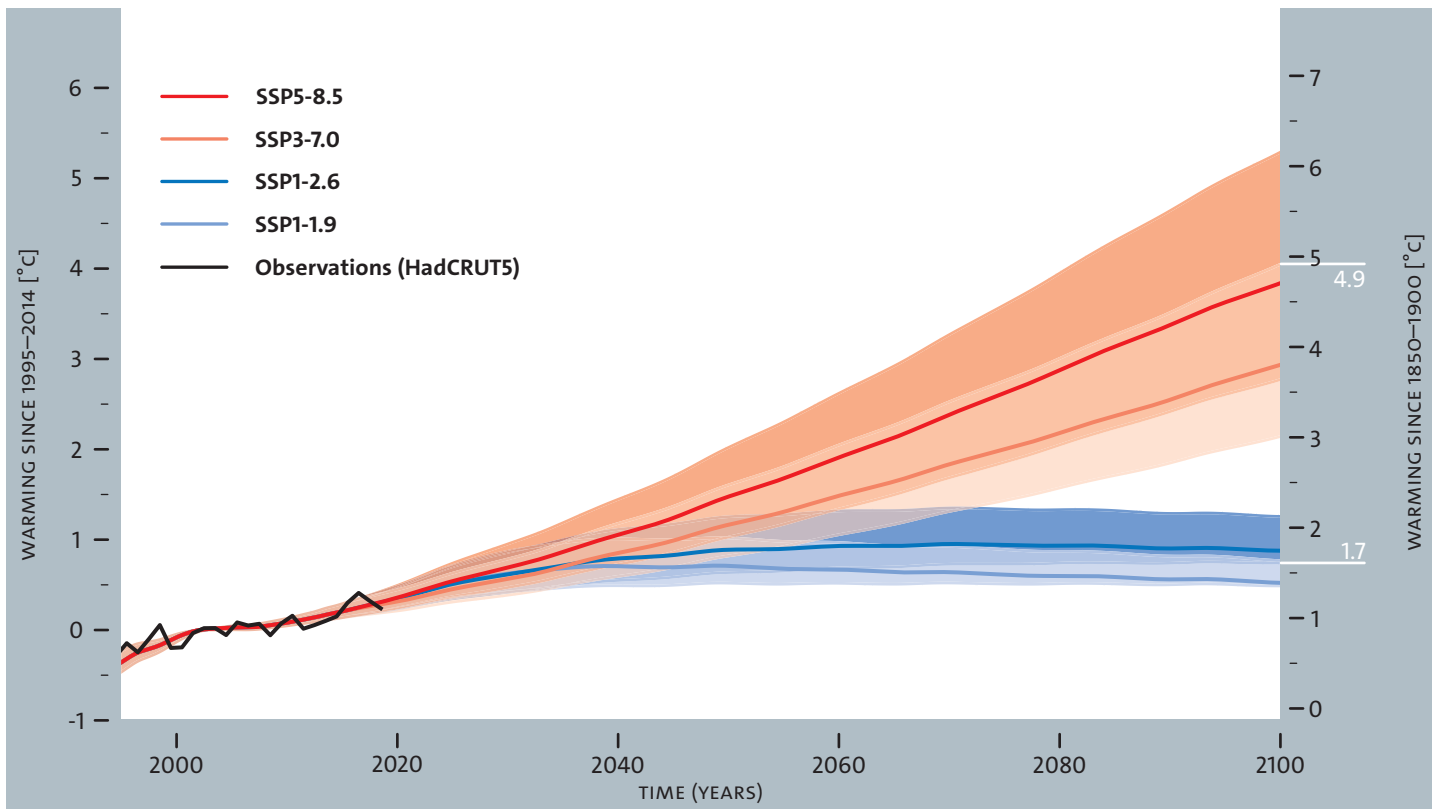


Figure 4: Projected 21st-century global surface warming, for the two lowest and the two highest high-priority SSP scenarios. The 90% uncertainty ranges are indicated by shading around the central estimates (lines). Observed global surface warming is shown by the black line (Morice et al., 2021). The warming is simulated relative to the recent reference period 1995–2014 (left vertical axis). To convert to warming relative to the pre-industrial period, we note that the period 1995–2014 was observed to be warmer than the period 1850–1900 by 0.87°C (Morice et al., 2021; right vertical axis). The numbers in white on the right vertical axis, 1.7°C and 4.9°C, indicate, respectively, the lower bound of the 90% uncertainty range in scenario SSP1-2.6 and the upper bound of the 90% uncertainty range in SSP3-7.0.

radiative forcing time series for all high-priority SSP scenarios provided by Smith (2020). These time series are used to drive a simple climate model (Held et al., 2010) designed to emulate the global surface warming simulated by comprehensive models. Using the emulator provides the crucial advantage that we can choose its parameters such that the emulator possesses any desired combination of ECS and TCR. Emulated surface warming can thus be made consistent with the newest 90% uncertainty ranges for ECS (2.3°C–4.7°C; Sherwood et al., 2020) and TCR (0.98°C–2.29°C; Tokarska et al., 2020). These warming estimates, including uncertainty bounds for ECS and TCR, are first evaluated relative to a well-observed recent reference period, 1995–2014. Warming information is often desired relative to the pre-industrial period, and the warming goals of the Paris Agreement are specified relative to pre-industrial levels (UNFCCC, 2015 Article 2). Following

the SR1.5, we thus use the average temperature over the period 1850–1900 as an approximation to the pre-industrial temperature, and we add the observed warming from 1850–1900 to 1995–2014, which is 0.87°C (Morice et al., 2021), to the projected time series (Figure 4).

We find that surface warming by 2100 of less than approximately 1.7°C relative to pre-industrial levels is not plausible, corresponding to the lower bound of the 90% uncertainty range in SSP1-2.6 (Figure 4). We furthermore find that surface warming by 2100 of more than approximately 4.9°C above pre-industrial levels is not plausible, corresponding to the upper bound of the 90% uncertainty range in SSP3-7.0. In particular, we find that limiting global warming to below 1.5°C is currently not plausible, given our current assessment of social drivers and climate sensitivity.

6.2

When would we see the effect of emissions reductions in global temperature?

If indeed greenhouse gas emissions are reduced at some point in time, how long would we have to wait to see the effect in the climate system—for example, by noting that the globally averaged surface warming has slowed down? The question is eminently policy-relevant, because policy-makers and society would expect to see a result of their effort to curb emissions after a time that is not too long on societal timescales. But the question is also eminently difficult to answer.

First, the effects of emissions reductions on surface warming can only be perceived as such if the effects are compared to some imagined (counterfactual) world, a world in which emissions reductions did not occur. But how much would this counterfactual world have warmed without these emissions reductions? Any such comparison involves some ad-hoc choices of what constitutes the counterfactual world and what emissions we would have expected without the emissions reductions.

Second, because CO₂ has such a long lifetime in the atmosphere, it takes time before emissions reductions can be detected in the CO₂ concentration. This is evident in the effect of COVID-19 lockdown measures on CO₂ emissions and concentrations. Despite the largest year-on-year decrease in emissions on record—larger even than that experienced

during the Second World War (Liu et al., 2020)—CO₂ concentrations are higher than ever before (see Box 4). In addition, the land and ocean sinks that absorb part of the anthropogenic emissions have large natural variability. Even though human-induced emissions drive the upward trend in atmospheric CO₂ concentrations on longer timescales, the large natural variability in the Earth system can dominate the year-to-year variations in these concentrations (Spring et al., 2020).

Third, while the surface warming trend responds to the assumed reduced increase in CO₂ concentration within a few years (Ricke and Caldeira, 2014), this slowing-down in warming trend is masked by internal variability. The time after which the difference in warming trend between high- and low-emitting scenarios can be detected against the masking has recently been estimated. Using different methods, models, and scenario comparisons, detection times have been found to be about five to ten years for CO₂ concentration (Tebaldi and Friedlingstein, 2013; Spring et al., 2020) and about twenty to thirty years for globally averaged surface temperature (Tebaldi and Friedlingstein, 2013; Marotzke, 2019; McKenna et al., 2020; Samset et al., 2020).

Figure 5 demonstrates some of these effects in a global climate model simulating two scenarios,

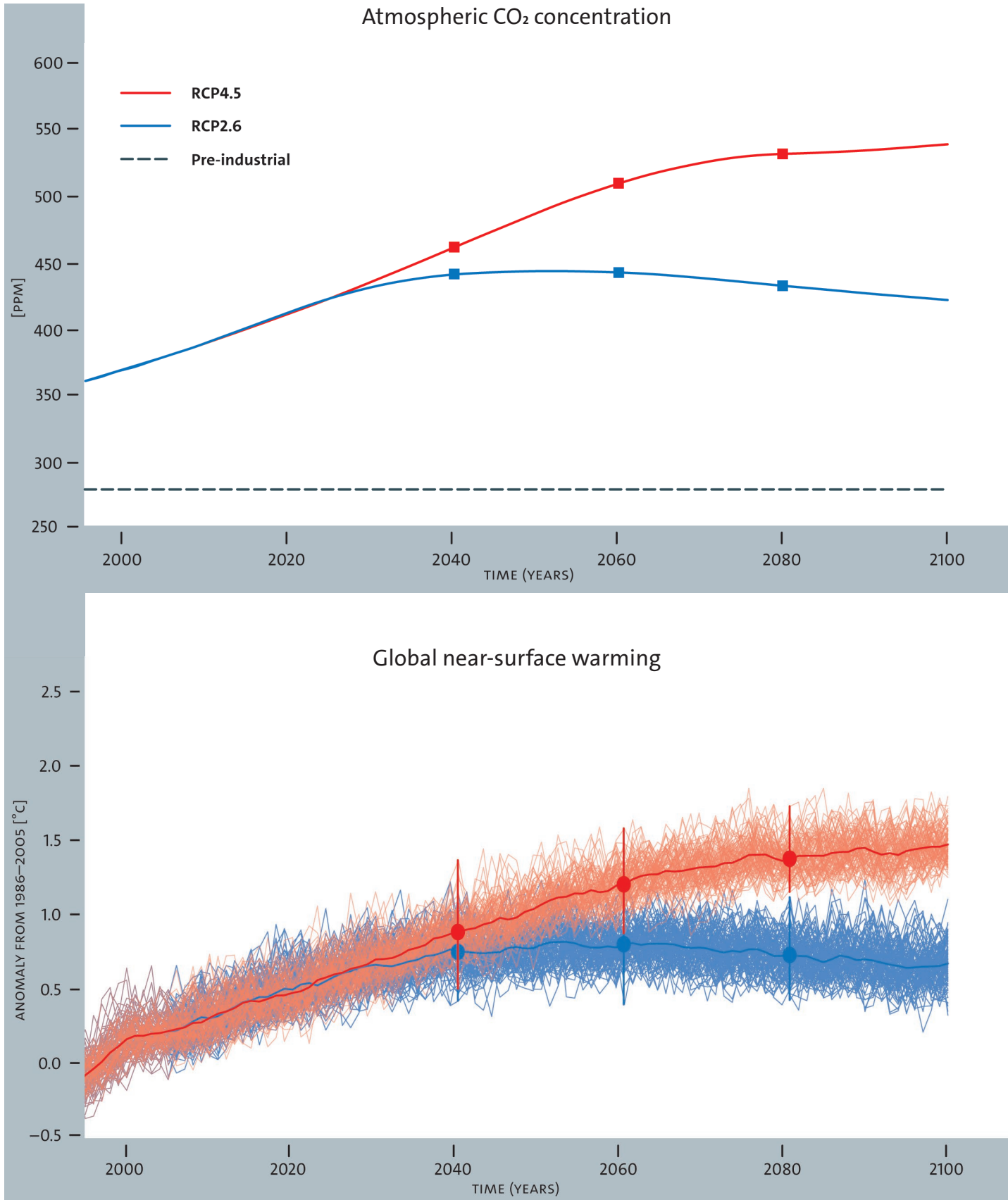


Figure 5: Detecting the effects of emissions reductions. Top figure shows atmospheric CO₂ concentrations for two emissions scenarios, RCP2.6 and RCP4.5. Bottom figure shows an ensemble of 100 global surface warming responses to each concentration pathway (generated by the MPI-ESM Grand Ensemble; Maher et al., 2019). The ensemble mean warming is shown by the thick lines, individual simulations by thin lines. The bars describe the range of warming generated by each ensemble for the years 2040, 2060 and 2080.

one with lower concentrations (RCP2.6) and one with higher concentrations (RCP4.5). The older RCP scenarios were used in the computationally intensive MPI-ESM Grand Ensemble (Maher et al., 2019) on which the figure is based. They are nevertheless similar in global forcing levels to the high-priority SSP scenarios SSP1-2.6 and SSP2-4.5, respectively. Each of the two scenarios was simulated 100 times in the Grand Ensemble to account for internal variability, which can cause warming to proceed temporarily faster or slower than expected.

Although the CO₂ concentrations in RCP2.6 and RCP4.5 have visibly diverged by 2030, global surface temperature change in many of the simulations still overlaps in the two scenarios by 2040. Fluctuations

in the climate could even lead the low emissions scenario (RCP2.6) to be warmer in the year 2040 than the scenario with higher emissions (RCP4.5). The overlap persists until after the year 2060. Note that the real world would correspond to one of the individual simulations and not to the ensemble mean, because the real world experiences internal climate variability, which is almost completely filtered out in the ensemble mean. Both Marotzke (2019) and Samset et al. (2020) have emphasized the substantial communication challenge that may well arise if—due to internal variability—the trend in surface warming would not decrease within fifteen years or so, in response to a reduction in CO₂ emissions.

6.3

Regional temperature trends and their uncertainty

Climate change is often summarized in terms of change in global surface warming. We do not, however, ever directly experience global warming—we experience regional or even local temperature and its fluctuation and change. Regional temperatures over land are more sensitive to increased greenhouse gas concentrations than the global average, because the drier land areas have less moisture available to dampen the warming effect than is the case for air over the ocean (Sutton et al., 2007). As a result, small changes in warming at the global level can be amplified at the regional level. Figure 6 shows how European summer temperatures might respond to different levels of global surface warming, as simulated by a climate model ensemble (Suarez-Gutierrez et al., 2018). Limiting warming to 1.5°C at the global level would result in an increase in European summer temperatures of roughly 2°C on average, whereas permitting global surface warming to increase by only half a degree more, to 2°C, would correspond to an increase in European summer temperature of over 3°C.

However, regional temperatures are also more variable than the global surface temperature, because internal climate variability is intensified at smaller scales. The variability of European summer temperature means that there is a great deal of similarity between a 1.5°C and a 2°C warmer world (Figure 6). There is a high degree of overlap in the distributions—albeit with different frequencies. Only some extreme temperatures in the 2°C world lie outside the range of 1.5°C and vice versa. Therefore, even if the plausibility of reaching the 1.5°C target increases in future years, the strong variability of regional temperatures implies a substantial adaptation challenge.

Authors:

Jochem Marotzke, Christopher Hedemann, Sebastian Milinski, Laura Suárez-Gutiérrez

Box 4: Eduardo Gresse, Christopher Hedemann, Jan Petzold

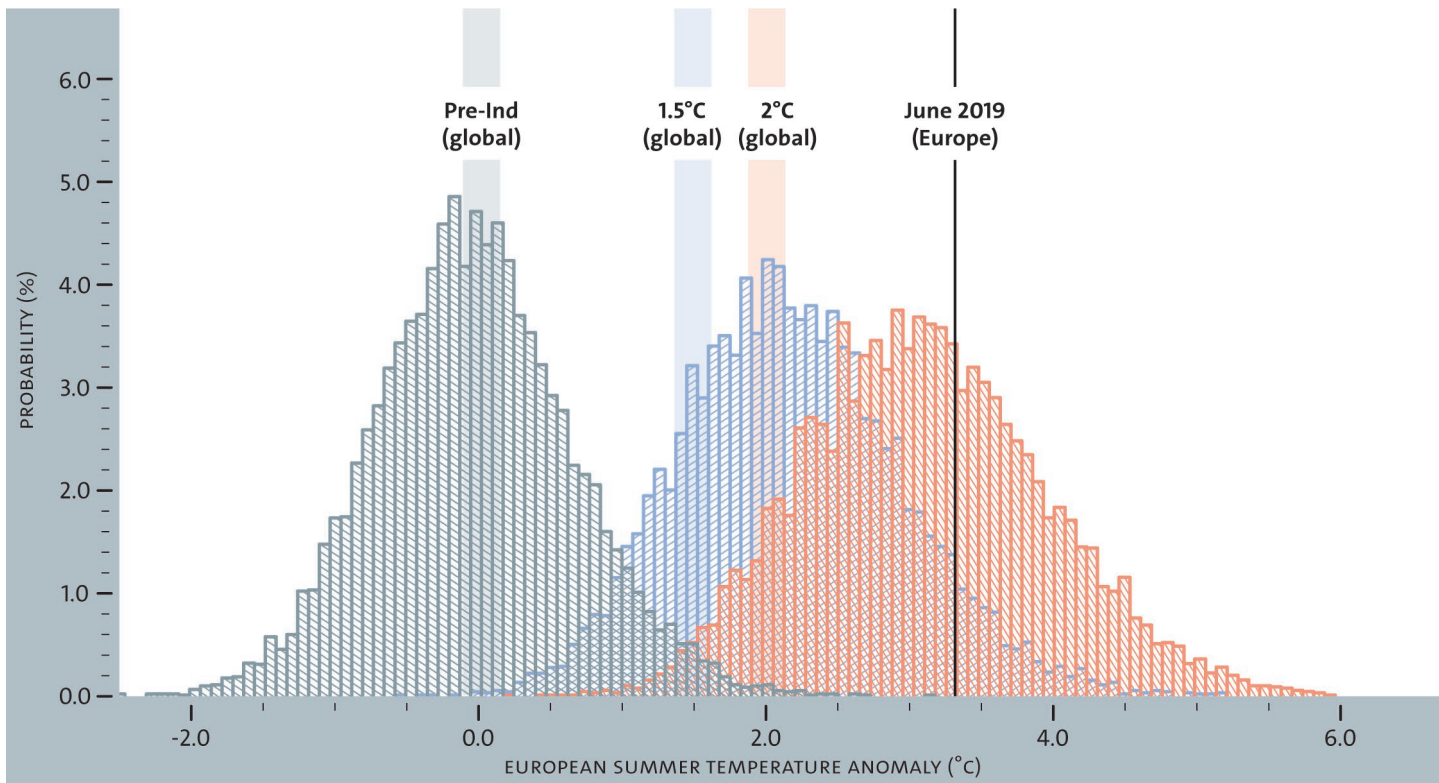


Figure 6: Amplified regional internal variability. Simulations with the MPI Grand Ensemble are grouped according to when the global and decadal average surface temperature shows no warming (pre-industrial, pre-ind), or when it is warmer than the pre-industrial by either 1.5°C (blue) or 2°C (red). For each such decade, the figure shows how often the European annual summer temperature attains a certain value. The summer values are grouped in intervals of 0.075°C. Adapted from Suarez-Gutierrez et al. (2018).

BOX IV COVID-19 and the changing climate

The COVID-19 pandemic has led to worldwide drastic lockdown measures, which in turn have temporarily reduced global greenhouse gas emissions. The emissions reductions are unprecedented and the year-to-year change is much greater than that experienced during the 2008 financial crisis or the Second World War (Liu et al., 2020). Estimates made using varying methods in the course of 2020 found that the reduction in CO₂ was around 7% over 2019 levels (Le Quéré et al., 2021). What effect might this reduction have on the pace of global warming? Forster et al. (2020) model the effect of an even larger emissions reduction on global temperature. They assume around 11% reduction in global emissions from the second half of 2020 until the end of 2021, and a linear return to baseline emissions by the end of 2022. Nevertheless, this rather generous projection of CO₂ reductions due to COVID-19 is estimated to have an impact of merely 0.01°C in avoided global surface warming (Forster et al., 2020).

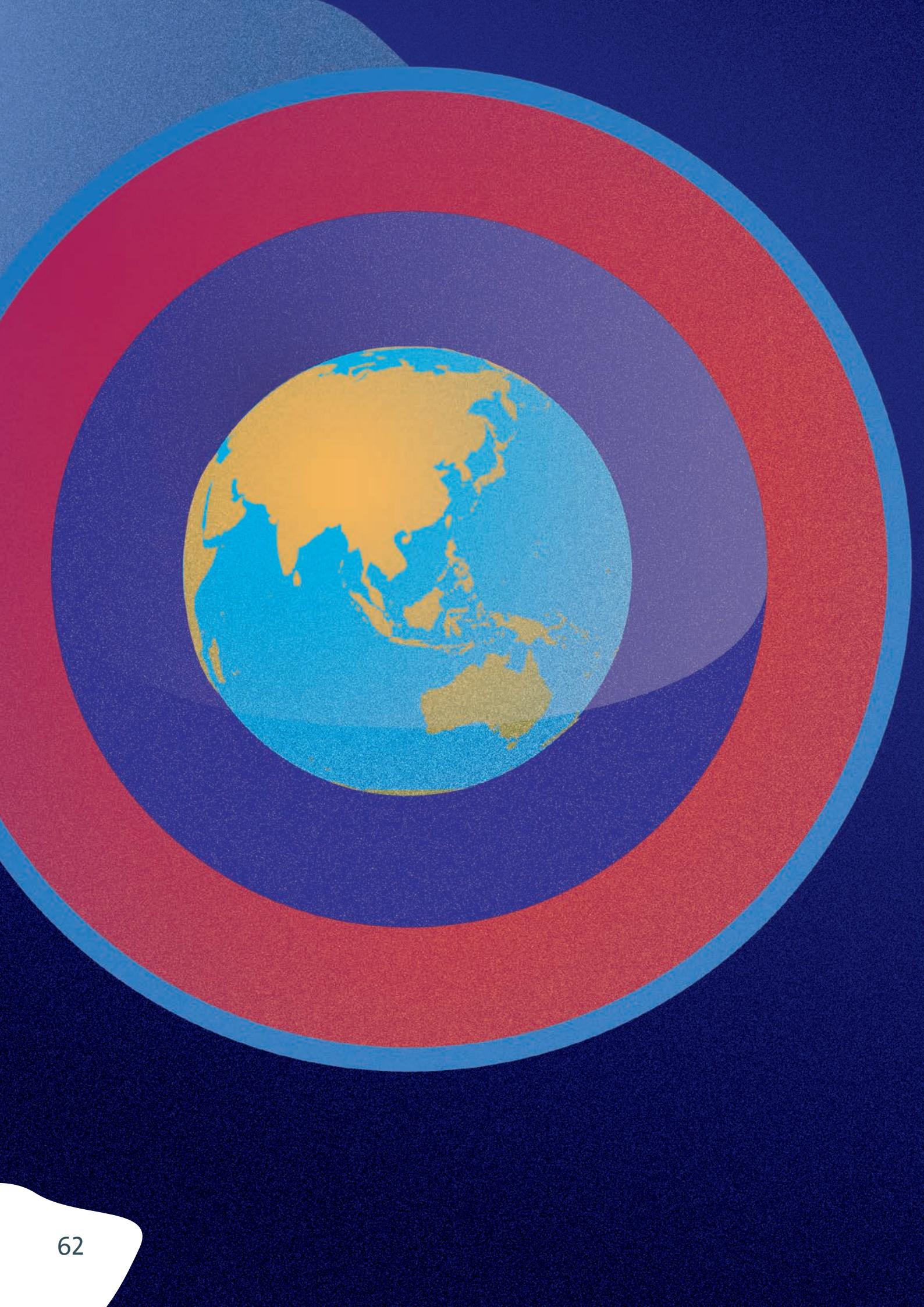
Why does a strong external shock to CO₂ emissions like the COVID-19 lockdown have so little effect on surface temperature? It is not directly the emissions but rather the atmospheric concentration of CO₂ that determines surface warming. Short-term, partial emissions reductions do not prevent the concentration from increasing. The CO₂ concentration measured at the top of Germany's Zugspitze broke new records in 2020, as did the measurement on Hawaii's Mauna Loa (DKK, 2020). To limit CO₂ concentrations to a level compatible with the Paris Agreement's 1.5°-target would require more than a one-off reduction in emissions of 7%, it would require year-on-year CO₂ emissions reductions, reaching 45% of their 2010 levels by 2030, and net-zero emissions by 2050 (IPCC, 2018b).

Nevertheless, the COVID-19 pandemic represents a window of opportunity for long-term progress toward decarbonization (Gawel and Lehmann, 2020). Disruptions like the pandemic can provoke societal changes at unprecedented speed, such as policy interventions (Herrero and Thornton, 2020), compliance with sudden new rules and social norms, and the rise of grassroots solidarity movements (Décobert, 2020; Ortega and Orsini, 2020). There is a strong case for using the window of opportunity presented by the pandemic to start "an economic recovery that puts emissions reduction [...] at its heart" (Howarth et al., 2020: 1113).

Indeed, a green recovery is considered by many to be the most reasonable way forward after the lockdown (UBA, 2020b; UBA, 2020c; IEA, 2020c; UNEP, 2020a). Incentives for climate-friendly transportation, remote communications and large-scale deployment of renewable energy could form key

strategic actions for immediate and lasting emissions reductions (Le Quéré et al., 2021). Moreover, the economic costs of mitigation measures that meet the Paris Agreement may be lower than previously thought, due to COVID-related reductions in economic activity. Such costs are also a fraction of those required for the COVID-19 recovery stimulus (Andrijevic et al., 2020; Meles et al., 2020), so that the implementation of ambitious mitigation measures may now be more feasible than before the pandemic (Klenert et al., 2020).

However, positive environmental impacts of lockdown strategies may be temporary, subject to rebound effects, or simply insufficient to bring about the change necessary for deep decarbonization. The emissions reduction due to the lockdown (Elliott et al., 2020) and most of the measures to promote economic recovery are currently not in line with the goal of reaching net-zero emissions by 2050 (Meles et al., 2020). So far, no structural transformations in the economic or energy systems can be observed (Beltermann et al., 2020; IEA, 2020d; Le Quéré et al., 2020) and it is plausible that the worldwide responses to the COVID-19 pandemic will trigger rebound effects in global emissions (see e.g., Wang et al., 2020). Global electricity demand rebounded sharply by the end of 2020 and is back to pre-COVID trends, and coal-fired generation is expected to bounce back in 2021, resulting in an approximate 2% increase in CO₂ emissions from the power sector (IEA, 2021a). Indeed, the powerful fossil fuel industries are lobbying for a fossil-fuel-based recovery (Gawel and Lehmann, 2020; Lenzen et al., 2020; Mukanjari and Sterner, 2020). Hence, whether the pandemic will significantly influence the pathway toward deep decarbonization depends not only on political decision-making, but also on the potential for long-lasting normative and behavioral changes toward a low-carbon global society (Messner, 2015; Sovacool et al., 2020).





Implications for climate futures

Implications for climate futures

The findings of this *Hamburg Climate Futures Outlook* present the currently available evidence for how physical and social dynamics influence climate futures. By combining physical and social plausibility assessments, we go beyond previous considerations of normative desirability or techno-economic feasibility (Box 1). The social plausibility assessment compels us to characterize the scenario of deep decarbonization by 2050 (Section 3.4) as currently not plausible (Section 5.3.1). Our assessment also shows the conditions under which the driver dynamics might change substantially and increase the plausibility of deep decarbonization by 2050 (Section 5.3.3). Our joint social and techno-economic plausibility assessments allow us to characterize both the highest and the lowest of the high-priority SSP scenarios as not plausible. Combining this finding with new assessments of climate sensitivity provides new upper and lower bounds for plausible global surface warming during the twenty-first century. We find that surface warming by 2100 of less than approximately 1.7°C relative to pre-industrial levels is not plausible, as is surface warming of more than approximately 4.9°C. In particular, we find that limiting global warming to below 1.5°C is currently not plausible (Section 6.1).

Our findings have several and in part opposing implications for climate action. First, societal actors who count on very low emissions scenarios and the lower end of the global surface warming range may feel greater urgency to increase the ambition and pace of climate mitigation and adaptation measures. By contrast, societal actors who orient themselves toward very high emissions scenarios and the higher end of the warming range might consider such futures to be less plausible, which could lead them toward reduced impetus for climate action. Finally, the uncertainty range for regional temperature change is shown to be larger than commonly appreciated (Section 6.3). Societal actors and decision-makers may therefore feel the need to re-evaluate what extremes in temperature they must prepare for.

Decision-makers must also consider future scenarios that include more than global and regional temperature changes. For developing appropriate adaptation strategies, changing precipitation patterns or sea-level changes may be more immediately relevant than temperature change. Possible trade-offs between different adaptation pathways, and between adaptation and mitigation strategies, must also be addressed in the policy process. Moreover, as important and urgent as climate change may be, it always competes for attention with other immediate problems that decision-makers must consider. Future versions of the *Hamburg*

Climate Futures Outlook may examine some of the processes that are involved in such decision-making for climate futures.

What does our assessment mean for climate futures? Deep decarbonization by 2050, while currently not plausible, is not impossible. However, if deep decarbonization is to be achieved by 2050, it requires increased societal pressure and political momentum for climate action, the implementation and worldwide diffusion of climate-friendly laws, policies, and infrastructures, and the redirection of financial resources away from fossil fuel engagements toward climate mitigation. We conclude from our social plausibility assessment that long-term pledges in line with deep decarbonization are insufficient on their own. Effective, short-term actions that align with these long-term pledges must also be taken in the coming decade. Otherwise, deep decarbonization by 2050 will indeed become impossible.

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PART II

Social driver assessments



Social driver assessments

- 8.1 UN climate governance
- 8.2 Transnational initiatives
- 8.3 Climate-related regulation
- 8.4 Climate protests and social movements
- 8.5 Climate litigation
- 8.6 Corporate responses
- 8.7 Fossil fuel divestment
- 8.8 Consumption patterns
- 8.9 Journalism
- 8.10 Knowledge production

8

Social drivers assessments

This chapter contains the full, in-depth assessments of the social drivers of decarbonization. These assessments form the basis of the social plausibility assessment in Chapter 5.

8.1

UN climate governance

Driver description

Despite a poor historic track record, international cooperation under the umbrella of the United Nations is widely considered as crucial for initiating and implementing a global low-carbon transformation. *UN climate governance*, as we understand it here, comprises state-led cooperation within the international climate change regime, that is, the bodies and provisions of the UN Framework Convention on Climate Change (UN, 1992) and climate-related activities of other international organizations in the wider climate change regime complex (Keohane and Victor, 2011). The wider UN regime also includes climate initiatives by private and subnational actors within the Paris Agreement's framework. Other transnational governance initiatives constitute a separate (but interconnected) driver (Section 8.2).

Historically, UN climate governance was based on a top-down approach with binding emissions reduction objectives for developed countries and the possibility to trade emissions reduction allowances and implement parts of these reductions in developing countries. But the 1997 Kyoto Protocol only fixed a global objective of 5% emissions reductions below 1990 levels for developed countries within the period 2008–2012 (Art. 3.1 Kyoto Protocol). Attempts to strengthen the treaty's ambition and extend its scope to emerging economies failed in Copenhagen in 2009. UN climate governance gained new momentum when the 2015 Paris conference put an end to a decade of “gridlock” in climate negotiations (Hale and Held, 2017; Kinley, 2017).

The Paris Agreement adopted at the 2015 conference is the first universal climate treaty with a quantified, indirectly actionable target: keeping warming “well below 2°C”, while aiming at 1.5°C (Art. 2.1a Paris Agreement). The treaty also aims to make financial flows consistent with this objective, by facilitating support from developed countries

and the biggest polluters for developing and vulnerable countries (Art. 2.1c Paris Agreement), and aims to achieve net-zero emissions in the second half of the century (Art. 4 Paris Agreement). The treaty's ambition hence roughly corresponds to deep decarbonization by 2050. Its implementation relies on a flexible pledge and review system (Falkner, 2016; Keohane and Victor, 2016) that combines the submission of freely determined country pledges (NDCs), an enhanced transparency framework to ensure their publicity and comparability, and a global stocktake every five years to evaluate the collective effort. Based on this assessment, countries are expected to ratchet up their pledges in the following round. However, despite this rationale, the Paris Agreement only establishes legally binding obligations of conduct, no individual obligations of result (Bodansky, 2016; Jacquet and Jamieson, 2016; Oberthür and Bodle, 2016; Rajamani, 2016). In addition to states, the post-Paris process also associates non-state actors, which are encouraged to submit voluntary commitments through a dedicated website (the Global Climate Action portal, also known as NAZCA) and process (the Marrakesh Partnerships for Global Climate Action). In sum, the Paris regime aims at building trust and aligning the expectations of states and private actors through a bottom-up approach, transparent reporting and polycentric governance. It marks a transition to a “catalytic and facilitative model” of governance (Hale, 2016). To build momentum for decarbonization, this model also relies on communicative tools and symbolic elements (Aykut et al., 2020b).

Moreover, global climate governance is directly affected by (non)decisions of other international organizations, such as the International Maritime Organization (IMO) and the International Civil Aviation Organization (ICAO). It is also indirectly affected by global trade governance, global energy governance, and global financial regulation. Insti-

tutional fragmentation and overlaps in global governance (Oberthür and Stokke, 2011) can lead to inefficiencies and *chilling effects* (Eckersley, 2004), for instance when provisions under the international trade regime dissuade governments from adopting ambitious climate regulations (Zengerling, 2020). Conversely, successful management of institutional interplay (Oberthür and Stokke, 2011) can lead to an efficient division of labor between international organizations (Gehring, 2011), such as when rules adopted under the ozone regime help to reduce greenhouse gas emissions (Kanter et al., 2013). Efforts to break up the *silozation* of climate governance (Aykut, 2016) and mainstream climate concerns in the policies, plans, budgets and activities of other international organizations (OECD, 2019) therefore constitute crucial components of driver dynamics.

Enabling and constraining conditions for effective UN climate governance

International regimes coordinate cooperation for collective action (Barrett, 2007) by aligning actors' expectations and practices (Krasner, 1983). They do so through the formulation of binding substantive and procedural rules and the harmonization of (national) law (Zartman, 1994), or through "soft" governance modes including the provision of positive or negative incentives (Abbott, 2018), capacity building, knowledge production and mobilization (Mitchell et al., 2006; Littoz-Monnet, 2017), agenda-setting, and the emission of signals and discourses (Death, 2011; Stripple and Bulkeley, 2014). The effectiveness of an international regime is a function of its levels of ambition, participation, and compliance (Bodansky, 2012). In the case of the Paris agreement, participation is almost universal and the ambition level of its long-term objectives high. However, compliance constitutes its Achilles' heel (Bang et al., 2016). The broader structural and institutional conditions that frame compliance and implementation fall into five broad categories (Bang et al., 2016; Keohane and Victor, 2016; van Asselt, 2016; Hermwille et al., 2019), as described below.

World politics and international order

Historically, the rise of international regimes has been associated with an era of US-led hegemonic stability (Keohane, 1984) and a liberal international order (Hale et al., 2013). However, anthropogenic climate change is a result of and a direct challenge to liberal globalization fueled by fossil fuels (Altvater, 2007; Newell and Paterson, 2010; Mitchell, 2011). Deep decarbonization therefore requires deep reforms of the international regulatory order. The emergence of China as a potential new superpower further complexifies the picture, as it both undermines US hegemony (Mearsheimer, 2019) and creates new opportunities for climate leadership (Engels, 2018). This means that UN climate governance is evolving in an uncertain and quickly chang-

ing geopolitical environment. This environment is marked on the one hand by growing distrust in multilateralism and new forms of illiberal authoritarianism in some countries, and on the other hand by new patterns of international leadership and followership (Torney, 2019). Changes in this environment affect both the implementation of the Paris Agreement and the prospects for wider reforms in the international regulatory order.

National policy environments

Global climate governance has been described as a "two-level game" in which domestic political forces condition the leeway of governments on the global level (Lisowski, 2002; Keohane and Victor, 2016). Whether the post-Paris process leads to substantial emissions reductions therefore depends crucially on the dynamics of domestic politics (Keohane and Victor, 2016). The picture has become more complex with the emergence of polycentric governance and the rise of private, federal, and communal climate politics (Chan et al., 2015). These can support the action of governments by additional commitments or complementary initiatives (see Section 8.3).

Social movements and global civil society

Effective global governance crucially depends on the capacity of global civil society to exert pressure on policy-makers. Hence, non-state actor engagement in international organizations can stimulate ambition by mobilizing public engagement, and enhance implementation by monitoring and evaluating compliance (Börzel and Risse, 2005). This is all the more relevant in voluntary schemes, where publicity is key to assure compliance (Hermwille et al., 2019). Active participation of NGOs, think tanks, and advocacy groups is therefore an essential feature for a successful post-Paris process (van Asselt, 2016; Chan et al., 2019). Moreover, the emergence of a transnational climate movement with the capacity to impose new frames centered on intergenerational and global climate justice has been identified as key for ambition and implementation at all levels of government (de Moor, 2017; Tormos-Aponte and García-López, 2018; see Section 8.4).

Energy technologies and corporate action

A key factor in governments' willingness to implement climate policy objectives is the fossil fuel dependence of the economy, which in turn frames the strength and direction of corporate lobbying (Newell, 2000; Bäckstrand et al., 2017). Shifting investment patterns (see Section 8.7) affect the availability of low-carbon technologies, and thereby alter the power balance between pro- and anti-climate coalitions within countries (Newell and Paterson, 1998; Newell, 2012). This shapes the overall incentive structures for global cooperation (Chan et al., 2015; We Mean Business, 2015). Moreover, private climate governance initiatives (see Section 8.2) can help governments reach their NDCs or independently close the gap to the Paris Agreement targets.

Discourses, knowledge, and norms

Finally, the work of epistemic communities (Haas et al., 1993) and discourse coalitions (Hajer, 1995) is crucial for global cooperation. Hence, developments in numerical climate modeling and the first Intergovernmental Panel on Climate Change (IPCC) assessments shaped the nascent climate change regime in the 1980s and 1990s (Dahan-Dalmedico, 2008; Edwards, 2010) (see Section 8.10). Conversely, climate science co-evolves with climate governance, as the example of the 1.5°C target has shown (Guillemot, 2017; Ourbak and Tubiana, 2017). Subsequently, competing discourses that depicted sustainability transitions alternatively as top-down environmental management, market-centered ecological modernization, or bottom-up civic environmentalism, profoundly influenced global climate politics (Bäckstrand and Lövbrand, 2007; Bäckstrand and Lövbrand, 2016). Post-Paris climate governance is also shaped by changing—and sometimes conflicting—narratives of risk, cost, and benefit.

Current driver dynamics and observations

UN climate governance is currently in a phase of transition, and a clear assessment is therefore difficult. In the following, we focus on interdependent elements of this transition (see e.g., Hermwille, 2020). We conclude that despite the momentum created by the Paris deal and a recent flourishing of net-zero carbon emissions pledges, current driver dynamics do not point toward deep decarbonization. Central elements of the pledge-, review-, and compliance-architecture are still not operational. Countries' NDCs are not aligned with the temperature target (UNFCCC, 2021b), and their implementation is not on track. Moreover, recent climate summits have failed to send positive signals to global stakeholders. Another severe shortcoming of the Paris regime is that it does not address the key issues of aviation, maritime transport, finance, and trade, which are so far insufficiently regulated by other international organizations.

Operationalizing the Paris framework

Since 2015, negotiations continued on fleshing out details of the Paris transparency framework, the global stocktake, differentiation rules, and the compliance-review mechanism. While transparency was further operationalized in the *2018 Katowice Rulebook*, a number of important aspects still remain unresolved after the 25th session of the Conference of the Parties (COP25) in Madrid (Aykut et al., 2020a; Biniiaz, 2020). In general, strong transparency, review, and compliance control provisions can establish incentives structures and reputational costs in ways that favor cooperation (Mason, 2020; Voigt and Gao, 2020). However, the relationship between transparency, accountability, and regime effectiveness is often more assumed than empirically scruti-

nized (Gupta et al., 2020; Mason, 2020). How the different elements of the “accountability continuum” of the Paris Agreement (Voigt and Gao, 2020) are further operationalized and implemented in practice is therefore key (Gupta and Van Asselt, 2019). In this regard, the “small” assessment and review cycle conducted in 2018–2020 was unsatisfactory. Assessments were mostly framed as technical, apolitical exercises, which avoided both individual naming and shaming and aggregate political judgement (Weikmans et al., 2020). Finally, the mandate of the Paris Agreement Implementation and Compliance Committee, which first met in 2020, is purely facilitative (Voigt and Gao, 2020) and has no enforcement component (Zengerling, 2013). However, a state-independent trigger remains, as there is an automatic initiation of a compliance review procedure if a party violates specific legally binding provisions of the Paris Agreement (Voigt and Gao, 2020: 47).

Implementing the agreement

The Paris Agreement rests on the expectation of a race to the top in the ambition of country pledges as successive submission cycles build trust (Jacquet and Jamieson, 2016). And indeed, a growing number of countries (including the European Union, China, Japan, South Korea, and the United States) and companies formulated net-zero carbon emissions pledges in 2020, including Long-Term Low Greenhouse Gas Emissions Development Strategies (LTS) and NDCs. At the time of writing, 19 LTS have been communicated (UNFCCC, 2021a). However, the operationalization and implementation of these pledges is subject to ongoing political disputes. A clear assessment is also difficult because most of these net-zero pledges have not yet been translated into official country submissions under the Paris Agreement. On the contrary, there is a persistent ambition gap in NDCs (Hohne et al., 2020; Streck, 2020). Studies find that if implemented, current NDCs and their logical continuation after 2030 would result in a likely temperature increase of 1.8°C to 3.4°C by 2100 (Liu and Raftery, 2021). Moreover, some countries are not even on track to achieve their current targets (UNEP, 2019), and while 103 states announced at COP25 their intention to submit more ambitious targets, others have declared that they will not.

Sending signals to a global audience

The Paris shift in UN climate governance also entails a renewed emphasis on communicative effects of climate summits, as transformative climate governance necessitates not only deep emissions cuts, but also building coalitions around “visions of attractive futures” (UNEP, 2019). Moreover, successful UN summits can help closing the coordination gap in climate governance (Lövbrand et al., 2017) by circulating positive narratives (Aykut et al., 2020a) and signals (Biniiaz, 2020). Conversely, setbacks can discourage global climate action. In this regard, COP25 struggled to deliver a positive signal to wider global audiences (Biniiaz, 2020). The conference's main ne-

gotiated outcome, the Chile Madrid Time of Action, is an aspirational document without major practical consequences (Streck, 2020: 143). It repeats previous decisions and re-emphasizes “the urgent need to address the significant gap between the aggregate effect of Parties’ mitigation efforts” and the Paris goals. Moreover, the COP has revealed deep cleavages between governments, some of which chose to merely “take note of” rather than “welcome” the recent IPCC reports.

Orchestrating the wider Paris regime

The wider Paris regime covers climate initiatives by private and subnational actors within the Paris framework, and climate-related activities by other UN organizations. Concerning private and subnational actors, the Non-State Actors Zone for Climate Action (NAZCA) portal for Global Climate Action registered over 18,000 submissions by the time of writing. Their effect is, however, highly uncertain as yet (Michaelowa and Michaelowa, 2017). Credible monitoring, reporting, and verifying obligations will therefore be key (more details are provided in Section 8.2). Concerning other UN organizations, some developments have occurred in the governance of aviation and maritime transport—two sectors with substantial and growing shares in global emissions (Murphy, 2020), which pose challenges in terms of emissions allocation (Kerr, 2020) and in which the pace of a multilateral response has been historically slow (Piera, 2016; Dobson, 2020). Under the International Civil Aviation Organization, states agreed in 2010 on a “carbon neutral growth” of the airline industry post-2020, a cap on growth of aviation’s emissions at 2020 levels, as well as a reduction of carbon emissions by 50% by 2050. These objectives rely on a framework for monitoring reporting and verifying CO₂ emissions and an offsetting mechanism to be implemented between 2021 and 2024. Under the International Maritime Organization, states established a decarbonization strategy in 2018 targeting a 50% reduction in greenhouse gas emissions from shipping by 2050, and a Global Data Collection scheme in 2019 for CO₂ emissions. The adequacy of these schemes with regards to the Paris goals, as well as the stringency of carbon market rules and monitoring, reporting, and verification provisions are however insufficient (Dobson, 2020). Further aligning these regimes—as well as global trade (Neumayer, 2017) and financial regulation (TCFD, 2016)—with deep decarbonization is a precondition for reaching the Paris goals.

Looking forward

An informed conjecture of future driver development can be made by complementing the observation of current driver dynamics with an analysis of the state of the driver’s enabling and constraining conditions. We find that the current geopolitical, societal, and economic context for UN climate governance is more favorable than it was at any point

since the beginning of the new millennium. Global youth protests and conducive national policy environments have put climate concerns high on the political agenda in key countries. Discernible changes in business practices, the availability of low-carbon technologies, and a discursive shift from negative impacts to economic opportunities of decarbonization have favorably altered the incentive structure for global cooperation. While this favorable constellation of enabling conditions opens a window of opportunity for global cooperation, some key obstacles remain. Continued fossil fuel dependence of key sectors in important countries create path dependencies. Moreover, the risk of authoritarian populist movements and persistent institutional fragmentation in international regulation threaten to undermine the potential for a positive driver dynamic.

World politics have returned into steadier waters after the election of Joe Biden as the 46th US President. This comes after a decade of increasing polarization, fueled by the Trump administration’s disdain of multilateralism and conflictual relations with China, with detrimental effects on climate diplomacy (Aykut et al., 2020a; Streck, 2020). This opens a window of opportunity for new alliances on low-carbon development. With its *Green Deal*, the European Union positioned itself as a frontrunner, but it still faces important internal conflicts over implementation. China has so far mostly acted as a ‘defensive co-operator’ (Eckersley, 2020), but its 2060 net-zero pledge—proposed independently from the United States, and outside of any UN governance scheme—shows its emerging interest in being perceived as a leader, albeit on its own terms. Despite these encouraging signs, however, the current uncertain global constellation makes bolder attempts to reform the international order and align key international regimes like trade and finance with decarbonization unlikely.

National policy environments also increasingly favor ambitious climate policy after the victory of US Democrats in both chambers of Congress, and ongoing discussions on implementing the Chinese, European, Japanese, and Korean net-zero pledges. Moreover, although the rise of illiberal and authoritarian populisms has, over the last decades, negatively affected national energy transitions (Selby, 2019), opinion polls still find consistently large support among major emitters for ambitious climate action, irrespective of other countries’ actions (Kachi et al., 2015; Bernauer et al., 2016) and irrespective of whether or not the costs of action are comparatively high (Kachi et al., 2015).

Social movements and global civil society have been crucial in raising the public profile of climate change over the last few years. Climate movements have been on the rise globally, especially in countries of the Global North, forming new alliances with low-carbon businesses. This development has caused decarbonization to appear as a major new existential social conflict in many jurisdictions (Colgan et al., 2020). Calls for Green (New) Deal

policies in Europe and the United States have been backed by large coalitions, including activists from the Fridays for Future and Sunrise movements. As a result, a growing number of governments have been implementing climate policies, regardless of what other countries do (Aklin and Mildemberger, 2020). If this trend continues, it would considerably enhance the prospects for UN climate governance.

Energy technologies and corporate action have also shifted in important ways over the last decade. Advances in renewables technologies have significantly altered the incentive structures of global cooperation, with plummeting prices leading to accelerated deployment even during the COVID-19 pandemic in 2020 (IEA, 2020d). However, other low-carbon technologies have stagnated. Although countries have started to address carbon removal politically in the context of net-zero greenhouse gas targets (Schenuit et al. 2021), appropriate governance frameworks are still lacking (Geden and Schenuit, 2020) and large-scale carbon dioxide removal is not realistically deployable within the coming decades (Fuss et al., 2014; Smith et al., 2016). Carbon capture and storage is still a long way from large-scale deployment (Consoli et al., 2017), while nuclear energy shows clear signs of decline (Markard et al., 2020). In energy-intensive industries, breakthrough technologies are still at early stages of development and face important market barriers (Oberthür et al., 2020). Moreover, non-state actor initiatives and pledges have been on the rise both in total numbers and ambition levels (see also Section 8.2). Progress in terms of outcomes and impacts is difficult to assess, due to data gaps and lack of common methodologies (Hsu et al., 2018). Moreover, most existing analyses focus on targets (ex-ante impact) instead of implementation (ex-post impact) (Hale et al., 2020). Nevertheless, it is reasonable to assume that this trend will continue to favorably affect driver dynamics in the future.

Discourses on climate action and climate-related norms have also shifted over the last decade, in line with social movement pressure and new knowledge about the economic and technical feasibility of energy transitions. In the Kyoto era, dominant frames were: stabilization to prevent dangerous climate change (Ott et al., 2004), and the design of cost-effective mitigation policies (Ipsen et al., 2001). After the Paris conference, sharply contrasting narratives of climate catastrophe and tipping cascades (Brauch et al., 2016), which depict climate change as a risk multiplier (Scheffran, 2016), coexist with positive narratives of an ongoing planetary transition (Aykut et al., 2020b), presenting new opportunities and (co-)benefits (Grin, 2016). Together with innovations in low-carbon energy technologies, this could facilitate the submission of more ambitious NDCs in the next Paris cycle.

In summary, UN climate governance, despite a poor historic record of accomplishment, now appears to be at a crossroads. Although current driver dynamics are not sufficient for deep decarbonization, a particularly favorable constellation of enabling conditions opens a window of opportunity for this driver. The next few years will therefore be crucial to see if a change in driver dynamics toward deep decarbonization becomes observable. Updated NDCs from a range of states are due at COP26, initially planned in 2020 in Glasgow but now postponed to 2021. Furthermore, the first global stocktake will take place over the years 2023-2025. Both will be crucial moments in which to observe how the new governance regime works in practice. So far, however, the premise that the Paris Agreement's pledge and review mechanisms could drive a race to the top is not supported by the evidence. And yet, UN climate governance might play a part in the global decarbonization effort by providing a platform for global climate debates and a lever for a growing transnational movement toward climate action and climate justice. The possibility of organizing large transnational events in the near future will be important in this respect. Moreover, the quick rebound in global transport emissions after the COVID-19 lockdowns in 2020 shows the importance of decisive action in fostering sectorial approaches to climate governance. A growing body of work therefore proposes "climate clubs" as a means to accelerate action in specific economic sectors (Victor and Jones, 2018), coordination treaties on green technologies (Barrett, 2016), or engagement in supply-side cooperation, such as the coal phase-out (Burke and Fishel, 2020).

Resources generated by this driver

Symbolically as well as politically, UN climate governance occupies a central position in global climate debates. UN climate summits regularly provide media attention for the climate problem and leverage for climate movements. The Paris Agreement's assessment and review cycles produce scheduling and agenda-setting effects for climate-related regulation in countries across the world. The regular meetings under the umbrella of the UNFCCC also constitute networking opportunities for transnational climate governance initiatives, notably through the Marrakesh Partnership for Global Climate Action. Moreover, the voluntary pledges submitted by firms, federated states and municipalities through the Global Climate Action Portal of the UNFCCC can be consulted by investors, think tanks, and NGOs. COP negotiations and outcomes also receive intensive and increasing media coverage, providing resources for journalism to build narratives of climate emergency and climate action for broader global audiences. Finally, the Paris Agreement constitutes a source of (legal) norms that is invoked in national debates and increasingly invoked in climate litigation cases against governments and companies around the world.

8.2

Transnational initiatives

Driver description

International climate politics have substantially evolved in the past decades and are no longer confined to international negotiations and governmental action. *Transnational initiatives* refer to new forms of climate governance that cut across traditional state-based jurisdictions and operate across public and private divides (Bulkeley et al., 2014). They encompass a wide variety of voluntary climate actions taken by subnational authorities, private businesses, civil society actors, and research institutions, who intend to coordinate across borders and produce collective effects to mitigate climate change. These stakeholders engage in a variety of initiatives that cover different thematic areas, forms of collaboration and geographical scopes (Hale et al., 2020). They also pursue a wide range of objectives and targets at multiple action levels (Bulkeley et al., 2014).

Academic literature distinguishes the following main types of transnational initiatives (Bulkeley et al., 2012):

- ▶ City networks coordinate and potentially catalyze mitigation efforts of municipalities. Among the key city networks are the Global Covenant of Mayors for Climate and Energy, the C40 Cities Climate Leadership Group, and ICLEI Local Governments for Sustainability (Gordon and Johnson, 2018; Heikkinen et al., 2018; Lee and Jung, 2018; Davidson et al., 2019; Kern, 2019; Zengerling, 2020). The Pact of Free Cities includes Central/Eastern European cities (Hřib et al., 2019).
- ▶ Regional collaborative schemes and market-based approaches can be designed to reduce emissions and are further discussed under the climate-related regulation driver (see Section 8.3).
- ▶ Transnational initiatives of NGOs aim to influence the activities of states or corporations to build collaborations, for instance on certification schemes for carbon offset credits (Hadden and Jasny, 2019), or on carbon disclosure and methodologies for decarbonization pathways. Examples include the Gold Standard for renewable energy and energy efficiency projects, the Community Carbon and Biodiversity Association standard, CDP (formerly Carbon Disclosure Project), the Science Based Targets initiative (SBTi), and the Assessing low Carbon Transition (ACT) initiative.

- ▶ Private sector transnational initiatives are business-driven initiatives on sustainability, low-carbon technologies, investments, and innovation (Knox-Hayes and Levy, 2011). For instance, private actors have developed initiatives to govern voluntary carbon markets, either through certification standards for offset markets or by developing trading exchanges, registries, and protocols for reporting greenhouse gas (such as Voluntary Carbon Standard, Social Carbon Standard). Other initiatives include the World Business Council for Sustainable Development (WBCSD), the Ceres Investor Network or Business for Social Responsibility (BSR; see Section 8.6).
- ▶ Public-private partnerships (PPP) for transnational initiatives involve governments, businesses, and civic organizations to facilitate commercial development and diffusion of low-carbon and renewable energy technologies, carbon markets, and sometimes adaptation (Pinkse and Kolk, 2011; Persson and Dzebo, 2019). There are numerous projects, such as the Renewable Energy and Energy Efficiency Partnership (REEEP), the Munich Climate Insurance Initiative, the World Bank Prototype Carbon Fund, the UN Global Compact Caring for Climate, and some UNFCCC Clean Development Mechanism (CDM) projects.

Justification

In the face of the persisting deadlocks observable in international climate negotiations, voluntary-based transnational initiatives have progressively become a central aspect of climate change responses (Chan et al., 2016a; Hale et al., 2020). Academic literature has identified their strong potential to fill part of the emissions gap resulting from unambitious NDCs on several grounds.

First, transnational initiatives innovatively address climate change in the sense that a broader spectrum of societal actors, connected transnationally, moves toward the achievement of the deep decarbonization goal (Bulkeley et al., 2014). Transnational initiatives are active in multiple carbon-intensive sectors, including energy, trade, transport, and agriculture (Chan et al., 2016a). They engage in a wide variety of activities, ranging from direct emissions reductions and technology transfer, to knowledge sharing, capacity building, and training. Some of them also coordinate the launch of pilot projects, funding programs, or business-to-business meetings (UNFCCC, 2019). This way, they actively encour-

age low-carbon investments, further the diffusion of green innovations, and facilitate learning and behavioral change (Bulkeley, 2010; Hakelberg, 2014).

Second, by diffusing inspiring success stories and best practices, voluntary climate actions convey a strong signal to the broader society that a deep transformation of the economies and society is taking place, and that the transition to a low-carbon economy is not only possible, but already happening (UNFCCC, 2019; Aykut et al., 2020a). This positive narrative, by altering actors' expectations and building trust, contributes to sustain political and societal momentum for climate action and can create a virtuous circle, whereby policy-makers, investors, and businesses are inspired to take further action (Bang et al., 2016; Chan et al., 2016a). With the shift from a top-down to a bottom-up, facilitative approach to climate governance, such positive story telling has become a central feature of the international climate regime (Aykut et al., 2020b). This is especially true for the engagement of businesses and investors. The latter have contributed to shift discourses from a pessimistic view of decarbonization as implying trade-offs in terms of economic growth and employment, to the potential of low-carbon transitions to drive technological innovations and bring about sustainable economic development (Chan et al., 2016a).

Contributions to climate governance

Transnational initiatives have progressively come to play a central role in climate governance that departs from the traditional view of global climate governance as involving merely states. Instead, this alternative view of climate governance assumes that the international climate regime encompasses the actions of both states and societal stakeholders, the interlinkages or overlaps between state and non-state actions co-determine collective outcomes (Chan et al., 2016a). Key examples for how the Paris regime integrates transnational initiatives are the NAZCA (Non-State Actors Zone for Climate Action) portal for Global Climate Action, where non-state actors are encouraged to register and display their actions, and the High-Level Champions, who are in charge of coordinating this stream with the overall UNFCCC process (Hale, 2016).

Academic literature has stressed the various benefits of engaging the groundswell of climate actions in the UNFCCC process: demonstrating broad societal support and building a momentum for climate action; inspiring other societal actors and governments to adopt practical, replicable, and scalable solutions to mitigate climate change; filling part of the gap to the NDCs; and formulating policy recommendations to accelerate climate action, thereby pushing states to consider more ambitious climate policies (Pattberg and Stripple, 2008; Andonova et al., 2009; Chan et al., 2016a).

With respect to policy recommendations, transnational initiatives are believed to have positively influenced state-led negotiations in the run-up to

COP21, ultimately contributing to reaching an ambitious outcome in Paris (Chan et al., 2016a). City mayors, for instance, have put decisive pressure on states by signing the Compact of Mayors in 2014 (Gesing, 2018).

Moreover, transnational initiatives can directly support the implementation of the Paris Agreement, either as complementary initiatives that help governments to reach their NDCs and implement corresponding mitigation measures, or as stand-alone initiatives proactively closing the gap between NDCs and mitigation needs of the Paris Agreement target (Michaelowa and Michaelowa, 2017).

As complementary initiatives, non-state and subnational actors can directly contribute to the implementation of national climate targets. Thereby, national governments may be incentivized to enhance their ambitions when taking into account non-state and subnational actions (Chan et al., 2016a). As stand-alone initiatives, transnational initiatives have a strong potential to compensate for unambitious NDCs or even replace them when national governments have retreated from their pledges, such as in the United States and Brazil (Kuramochi et al., 2020). In the United States, subnational and non-state climate actions, gathered under the initiative WeAreStillIn, ambitions to make up for the emissions reductions lost due to the process initiated by the Trump administration, between 2017 and 2020, to withdraw from the Paris Agreement. Studies have estimated that sub-national and non-state actions, primarily driven by 20 key US states including California and New York, could result in a level of emissions reductions similar to the country's original NDC, if entirely implemented (Kuramochi et al., 2020). Cities can be strategic partners of states and key implementers of national policies, but also can push or provoke national governments to take more assertive and aggressive climate policies, such as in the case of the so-called *California effect* (Gordon and Johnson, 2017).

Enabling and constraining conditions and linkages with other drivers

Academic literature has highlighted a number of enabling and constraining conditions in greenhouse gas emissions reductions by state-level actions and transnational initiatives (e.g., Overdevest and Zeitlin, 2012; Berliner and Prakash, 2014; Scheffran and Froese, 2016). An increase in ambition of state-level NDCs would create a signal for transnational initiatives that economies are moving toward deep decarbonization, and therefore encourage them to take further action. A key enabling condition is the orchestration of transnational initiatives (Chan and Pauw, 2014; Michaelowa and Michaelowa, 2017). In the context of a fragmented climate governance architecture, orchestration refers to efforts of international organizations or national governments to ensure coordination and synergies by organizing a "strategic ordering of polycentric climate governance" (Abbott et al., 2015). More specifically,

it consists of steering non-state and subnational actions toward particular goals and empowering them through a wide range of possible activities, including: initiating transnational initiatives, granting them institutional recognition and publicity, shaping their objectives and activities, providing them with capacity-building, institutional support, technical advice, and financial resources (Hale and Roger, 2014; Abbott et al., 2015; Hale, 2016). Such coordination could be managed by international organizations and national governments, but also expert networks or private organizations (Gordon and Johnson, 2017; Chan et al., 2019).

Other social drivers can also influence enabling conditions for transnational initiatives. For example, a more favorable regulatory environment (see Section 8.3) can strengthen the potential of transnational climate governance. Enhanced national-level regulations that give non-state actors competencies over their emissions scopes and over climate-related policies (such as carbon pricing) can help incentivize and send positive signals to transnational initiatives (Pfeifer and Sullivan, 2008; Sullivan, 2008; Hale et al., 2020). The initiatives in turn can reinforce this process by formulating their own policy recommendations for national governments (UNFCCC, 2019). Corporations (see Section 8.6) with membership in a transnational initiative can also influence its overall effectiveness, by engaging in decarbonization pathways and acting as an example of best practice for other members.

On the other hand, several constraining conditions limit the way for transnational initiatives to achieve their full potential. First, persistent underfunding and lack of organizational capacities have explained the low performance of partnerships for sustainable development launched during the 2002 World Summit on Sustainable Development (Chan and Pauw, 2014; Widerberg and Pattberg, 2015). More recent assessments confirm that beyond setting ambitious goals, organizational resources remain key challenges to ensure the robustness of transnational initiatives (Hale et al., 2020). Such resources include strong leadership, inclusive participation of actors from the North and the South, the availability of dedicated staff and budget, access to funding, and the establishment of credible planning, consisting of intermediate milestones and the potential development of an internal monitoring, reporting, and verification (MRV) structure (CAMDA, 2020; Hale et al., 2020).

Observations

Past and current driver dynamics

The last decades saw an exponential increase and diversification of transnational initiatives, as well as an increasing number of actors engaging in them (UNFCCC, 2019). The dynamics of transnational initiatives involvement in global governance began during the 1990s and an important step in their institutionalization was achieved at the 2002

World Summit for Sustainable Development (Chan and Pauw, 2014). However, an unprecedented window of opportunity for transnational initiatives has opened during the run-up to COP21 in Paris (Chan and Pauw, 2014). The UN system has played a decisive role in brokering new cooperative and individual climate actions, and in further linking them with the interstate regime. From 2011, the UNFCCC Secretariat brought the groundswell of climate actions under the spotlight, by launching the Momentum for Change campaign, and three years later, 52 actions involving around 1000 actors were launched during the 2014 UN Climate Summit (Chan et al., 2016a; Chan et al., 2016b). A number of new initiatives were also launched during the 2018 Global Climate Action Summit—around 500 in total—and at the 2019 UN Summit in the framework of the recently formed Climate Ambition Alliance (UNFCCC, 2019; Kuramochi et al., 2020). On this occasion, several businesses, investors, cities, and regions increased their level of ambition and pledged to achieve net-zero emissions by 2050. Their number almost doubled in one year to reach 826 cities, 103 regions, and 1565 companies in 2020, representing a total of around 10 Gt of greenhouse gas emissions (NewClimate Institute and DataDriven EnviroLab, 2020).

Today, transnational initiatives are active in many different sectors. The 2019 Yearbook for Climate Action (UNFCCC, 2019), a first attempt to trace transnational initiatives under NAZCA, identifies eight broad sectors, together with a cross-cutting area of action, namely climate finance, where cooperative climate action is currently taking place at global level:

- ▶ Land-use (Business for Nature, One Planet Business for Biodiversity)
- ▶ Oceans and coastal zones (Blue Carbon Initiatives)
- ▶ Water greenhouse gases (Megacities Alliance for Water and Climate, The Business Alliance for Water and Climate, BafWAC)
- ▶ Human settlements greenhouse gases (100% Renewable Energy Cities and Regions Network, C40 Cities)
- ▶ Transport (EcoMobility Alliance, EV100, Airport Carbon Accreditation, Global Fuel Economy Initiative, etc.)
- ▶ Energy (RE100, EP100, Cool Coalition, Global, en.lighten initiative, etc.)
- ▶ Industry greenhouse gas (We Mean Business, SteelZero initiative, Business Ambition for 1.5°C, etc.)
- ▶ Climate finance (Climate Action 100+, Climate Bonds Initiative, Task Force on Climate-related Financial Disclosure, Climate Investment Platform, etc.)

Assessments of potential contribution to climate governance

Due to its potential to close the emissions gap, transnational initiatives can constitute a key driver of decarbonization. Several studies have focused on estimating this mitigation potential (Hale et al., 2020; Kuramochi et al., 2020; Lui et al., 2021). Such assessment however, must consider the diversity of transnational initiatives types and objectives, as not all transnational initiatives directly pursue mitigation goals (Bulkeley et al., 2012; Michaelowa and Michaelowa, 2017; Dietzel, 2018). Furthermore, since a vast majority of mitigation initiatives pursue networking purposes, they have not adopted a clear mitigation-oriented design, consisting in baselines, mitigation incentives as well as monitoring, reporting, and verification procedures to follow-up on progress. Hence, their actual contribution to fill the mitigation gap is rather limited (Michaelowa and Michaelowa, 2017). Assessments of mitigation-oriented initiatives with quantitative targets have derived encouraging results (Hsu et al., 2018; Hale et al., 2020; Kuramochi et al., 2020; Lui et al., 2021). On the one hand, individual commitments from non-state and subnational actors could bring additional greenhouse gas emissions reductions, but not enough to bring about deep decarbonization (Hsu et al., 2018; Kuramochi et al., 2020). On the other hand, the full implementation of a limited number (17) of very ambitious cooperative transnational initiatives, in particular those concerning cities and regions, businesses and forestry, would reduce global emissions in 2030 by 18–21 GtCO₂-eq per year. Combined with the implementation of current national policies, and provided that they do not lead to changes in emissions reductions elsewhere, these voluntary climate actions could bring the global emissions trajectory toward a range consistent with a 2°C temperature increase by the end of the century, although a significant gap would remain to reach a 1.5°C-consistent pathway (Lui et al., 2021). Credible contributions of non-state actions thus require minimum standards and guarantees for ambitions, and a comprehensive follow-up of progress in achieving greenhouse gas emissions reductions. Furthermore, knowledge gaps persist around ex-post achievement of results and around impacts of transnational initiatives in a shift from negotiation to implementation (Hale et al., 2020).

Assessments of actual contributions to climate governance

While transnational initiatives have been on the rise in total numbers, ambition levels, and visibility, their actual effects are notoriously difficult to assess and have been subject to debate (Bulkeley et al., 2014; Michaelowa and Michaelowa, 2017). One of the notorious problems may be the double accounting of reduction commitments, which is analogous to the double counting of development aid as climate financial aid. Their progress in terms of outcomes and impacts is difficult to assess, because of

data gaps and lack of common methodologies and frameworks to quantify achievements (Gordon and Johnson, 2018; Hsu et al., 2018; Zengerling, 2020). For instance, the NAZCA portal for Global Climate Action communicates pledges and not achievements, so that the extent to which its large outreach will translate into actual mitigation effects needs to be considered carefully. Assessing the effectiveness of climate actions in filling the mitigation gap is virtual impossible, due to the large variety in actors and types of initiatives, the diversity of their scopes and sectors, the lack of (comparable) design criteria such as greenhouse gas emissions reduction targets, and the lack of common accounting, monitoring, and reporting architecture. For example, calculation of aggregated mitigation efforts in cities or city networks mitigation efforts is complicated by the fact that cities' greenhouse gas inventories and accounting methods are highly different, although they have recently been improved (Gordon and Johnson, 2018; Hsu et al., 2020; Zengerling, 2020). In addition, current reporting and accounting—including under the NAZCA portal—is facilitated by non-profit organizations such as CDP (formerly the Carbon Disclosure Project) or the Global Reporting Initiative (GRI), which do not provide transparent public access to data and methodologies.

As a result, existing analyses mostly focus on targets adopted (ex-ante impact) instead of implementation or even effectiveness compared to a defined decarbonization trajectory (ex-post impact; Hale et al., 2020). Some of the very few studies that assess the implementation of transnational initiatives use the number of outputs produced (such as events, publications, norms and standards, and physical installations) as an indicator, since these inputs increase the likelihood of achieving desired environmental and social impacts (Chan et al., 2016b; UNFCCC, 2019). A recent assessment of 52 transnational actions launched at the 2014 UN Climate Summit in New York suggest that more recent climate actions have a better output performance than previous initiatives initiated during 2002 World Summit on Sustainable Development, many of which did not produce any output at all (Chan et al., 2016b). One interesting assessment of progress concerns cities' achievement of announced targets (Hsu et al., 2020). It shows that 60% of more than 1,000 EU Covenant of Mayors' cities have achieved their 2020 emissions reduction targets, although it observes that high performance is often correlated with less ambitious initial targets, higher baseline emissions, and more-ambitious national-level climate policies. Overall, combined assessments of the alignment of adopted targets with the “well-below 2°C” decarbonization goal and of ex-post achievement of targets are missing.

Evolution of enabling and constraining conditions

The last years saw an increase in efforts to better orchestrate transnational initiatives. The UNFCCC framework has developed a set of mechanisms and institutional innovations that further integrate and coordinate transnational initiatives in the global regime. The NAZCA portal for Global Climate Action on the UNFCCC website, on which transnational initiatives can register their actions, provides them with visibility to a large audience. At the time of writing, a total of 18,241 voluntary pledges are registered on the NAZCA portal, including pledges by individual companies and cities, and a number of multi-stakeholder cooperative initiatives. The Marrakech Partnership for Global Climate Action was launched during COP22 with the objective to further associate non-state actors with mitigation efforts and needs-assessments in the pre-2020 period. Leadership and coordination with the UNFCCC process is ensured by High-level Champions, prominent figures from the sustainability sector designated by COP Presidencies for a two-year mandate, while the UNFCCC Yearbook for Global Climate Action presents regular compilations of best practices and success stories to facilitate peer-to-peer learning, inform policy-makers on policy options, and secure their support (UNFCCC, 2019). Furthermore, annual COPs constitute key moments for transnational initiatives to gain visibility and strengthen their action (Chan et al., 2016b; Aykut et al., 2020a). New formats have been created to stage actions, make announcements, share best practices, and provide recommendations to policy-makers, including the Technical Examination process, the Talanoa Dialogue, and a dedicated space for transnational initiatives—the Climate Action Hub (Aykut et al., 2020a). These new formats contribute to a better recognition of the potential of transnational initiatives to complement NDCs toward deep decarbonization (Chan et al., 2016a).

On the other hand, assessments of participation in transnational initiatives reveal that despite efforts to involve actors from developing countries, northern-based actors are still overly represented in individual and cooperative climate actions. This bias concerns both leadership and membership in transnational initiatives, as well as the geographical scope of implemented actions (Chan et al., 2016b; UNFCCC, 2019; Data-Driven EnviroLab and NewClimate Institute, 2020). This trend is particularly observable for city networks, with large and smaller European cities (especially Italian or Spanish cities) accounting for the large majority of membership in the Global Covenant of Mayors (Heikkinen et al., 2018; Zengerling, 2020). Consequently, developing countries have limited power to influence the definition of objectives and activities to tackle their needs, so that climate actions mostly benefit higher-income economies. This lack of ownership and participation raises critical questions about the effectiveness of transnational initiatives, as most of future growth in greenhouse gas emissions is expected in developing or emerging countries (Chan et al., 2016b). Finally, transnation-

al initiatives suffer from persistent lack of funding, which constitutes a major obstacle for their effective contribution to climate mitigation (UNFCCC, 2019).

In this sense, the effects of the COVID-19 crisis on transnational climate governance are highly uncertain and hardly measurable at the time of writing. The extent of aligning recovery plans with the Paris goals will determine the future effectiveness of transnational initiatives in filling the mitigation gap.

Looking forward

Potential risk of transnational initiatives in threatening the overall effectiveness of climate governance

The increasing importance given to transnational initiatives in climate governance raises some fundamental questions. First, their proliferation in the past decades has increased the complexity and engendered further fragmentation of the climate regime. On the one hand, this could increase synergies between climate actions by state and non-state actors, by promoting cross-learning, innovation, and experimentation (Chan and Pauw, 2014). On the other hand, it could also contribute to dilution of state responsibility for achieving greenhouse gas emissions reductions, as well as bring additional inefficiency and transaction costs in the regime (Chan et al., 2016a). The increased importance occupied by transnational governance initiatives may also result in the exacerbation of power imbalances and asymmetries between northern-based and southern-based state and non-state actors in climate governance (Chan and Pauw, 2014).

Another potential risk consists in an increasing privatization of climate governance, whereby business interests dictate a pace and trajectory of decarbonization favorable to business-as-usual and prevent stricter government regulations, or instrumentalize climate action for greenwashing and strategic communication purposes (Chan and Pauw, 2014; Chan et al., 2016a; Aykut et al., 2020a). The poor effectiveness of transnational initiatives could also constitute a waste of resources and ultimately undermine mitigation efforts. In fact, private initiatives and public-private partnerships have sometimes been criticized for not being socially and economically sustainable in the long-run (Santarius et al., 2012). Such risk could be aggravated by the lack of screening procedures and minimal requirements for participating initiatives (Chan and Pauw, 2014) or lack of follow-up. Critical research on cities confirms this caveat. Membership in a city network does not require ambitious climate reduction targets (Zengerling, 2020). In practice, adopted measures often do not significantly go beyond the status quo, except for specific programs (such as Deadline 2020 of C40, or the initiative Under2MoU), and thus will most likely not unfold transformative changes in urban greenhouse gas emissions under the current frameworks (Gordon and Johnson, 2018; Heikkinen et al., 2018; Zengerling, 2020).

Conditions for more effectiveness in the future

Hence, while transnational initiatives have been on the rise both in numbers and ambition, several conditions need to be met so they can effectively constitute a driver of deep decarbonization. A first challenge consists in defining standardized and actor-specific definitions of net-zero ambitions. Current pledges display a large variety of understanding, in terms of scope of emissions covered, use of offset mechanisms, and support for carbon-dioxide removal (CDR). Such nuances in the details of implementation will ultimately affect the impact and integrity of claimed outcomes of voluntary climate actions (NewClimate Institute and DataDriven EnviroLab, 2020). Additionally, efforts will have to be increasingly devoted to operationalizing declarations and implementing existing commitments in the future, especially concerning high-potential initiatives (Chan et al., 2016a).

In order to assess their progress in implementation and their effectiveness in filling the mitigation gap, establishing credible and standardized monitoring, reporting, and verification (MRV) obligations for each initiative will be key. The RaceToZero campaign launched under the UNFCCC and coordinated by the High-Level Champions for Climate Action might help develop such a harmonized MRV structure. Furthermore, creating a global framework for tracking the overall progress of transnational initiatives is paramount (Chan et al., 2016a). Current efforts to strengthen the NAZCA portal and provide harmonized methodologies and indicators to assess mitigation actions could help bring more transparency and coordination in transnational climate governance. In 2023, the global stocktake conducted under the UNFCCC process, if properly designed, could also constitute a decisive moment for assessing actual greenhouse gas emissions reductions of transnational initiatives.

Strengthening the Global Climate Action agenda within the UNFCCC in the future would ensure that the potential of transnational initiatives is realized. The UNFCCC Secretariat could provide further visibility to scalable solutions, especially during high-level events, and suggest tailored ways to leverage on non-state climate actions in particular regional or national contexts. Moreover, supporting the integration of non-state actions in NDCs would ensure that transnational initiatives actively complement and support the much-needed increase in state-level ambitions. Consequently, transnational initiatives could become a strong driving force of the “ratchet mechanism” toward meeting the Paris climate goals (Kuramochi et al., 2020).

Finally, scaling up climate finance and aligning financial flows with the deep decarbonization goal would provide additional resources to implement non-state actions. The adoption of ambitious long-term mitigation targets, policy instruments, and carbon market regulations at national level would create the necessary incentives for businesses to engage further in coordinated climate actions (Berliner and Prakash, 2014). The relevance of transnational initiatives could be all the more visible in a future where national-level mitigation ambitions are declined into specific sectoral or subnational targets.

Resources generated by this driver

Notwithstanding the risks mentioned above, strengthened transnational initiatives could also provide resources for a global opportunity structure. Transnational initiatives can support the formulation and implementation of individual corporate decarbonization strategies, by establishing standard definitions and accounting and reporting methodologies, and providing capacity-building and training. Voluntary schemes supplied by transnational initiatives, such as market-based instruments and partnerships, can also provide economic incentives for corporations to engage in decarbonization. Finally, transnational initiatives can also help build and share knowledge within their networks and with other societal actors, including best-practice sharing, capacity building, providing expertise, and policy recommendations, which can provide resources to other drivers of deep decarbonization.

8.3

Climate-related regulation

Driver description

Climate-related regulation refers here to legislation and regulation issued by national and supra-national government bodies. Climate-related regulation intends to limit or reduce the concentration of greenhouse gases in the atmosphere, either by limiting their emissions or by withdrawing them from the atmosphere. A wider understanding of climate-related regulation would also include measures relating to climate change adaptation, but this driver assessment relates to the deep decarbonization scenario, for which greenhouse gas emissions and their removal are most relevant.

Climate-related regulation is a deliberate attempt by governmental institutions to steer the future dynamics of climate-relevant processes and at least one related target variable—for example greenhouse gas emissions, fossil fuel use, mobility choices, energy supply from renewable sources, or energy efficiency—in a social system by changing economic incentives, legally feasible options, or procedures. The regulator tries to achieve an objective that is often operationalized in terms of primary emissions targets and sub-target variables (such as the share of renewables or energy efficiency) by drawing on knowledge about the interactions between these targets (including potential conflicts), and the specific behaviors that affect the targets and are addressed by climate-related regulation. The better informed the policy-maker is about the technical and social systems involved, the more successful she will be in converting her intentions into policy.

However, regulation is not a one-way or one-off activity. Governments and regulatory agencies are themselves part of social systems, including the very systems that they are trying to steer. Many factors in the policy-making process are in fact outcomes of the current state of society, including the objective of a regulation, the knowledge base used to inform it, the stringency of the regulation, and the feasibility of specific policy designs. Policy tends furthermore to develop as an iterative process rather than in one coherent policy switch. For example, policies are often “sequenced” (Pahle et al., 2018), which entails the ramping up and expansion of interventions rather than immediate implementation in their full stringency. This not only reflects responses to new scientific insights but also to changes in what is considered to be politically feasible. Climate-related regulation is a cross-cutting issue (Koch, 2011: 642) encompassing and affecting an exceptionally large set of highly diverse areas, sectors and sections of law and public policy. There is also significant spatial heterogeneity in terms of targets and instruments.

Effect of climate-related regulation on deep decarbonization

The scenario deep decarbonization, defined as net-zero CO₂ emissions by 2050, represents a target in the sense described above. The set of climate-related regulation instruments applied is probably the single most important factor for attaining the target. The regulator can choose from a variety of instruments based on different mechanisms to reach the policy goal. These instruments comprise command-and-control instruments, market-based instruments using economic incentives, planning, consent-based instruments, or informational instruments.

The resulting legal framework determines which abatement (and emissions) strategies pay off, in both a financial and non-financial sense. A framework may determine, both directly and indirectly, the goods and services producers can offer, the goods, services and lifestyles consumers can choose from, the information accessible about products, and the physical infrastructure available (see Section 8.8). Climate-related regulation is the essential link that translates a society’s values into a binding framework for companies, individuals, and the administration itself.

Enabling and constraining conditions

Climate-related regulation rests on the ability of a state to function, that is, stable public institutions, effective state authority, and officials’ integrity. Whether climate-related regulation contributes directly to achieving deep decarbonization as a goal depends on policy design, such as setting the right goals, choosing adequate instruments, and effective implementation and enforcement. Each of these components interacts with other societal dynamics.

The effect that instruments of climate-related regulation have on specific behaviors and outcomes depends crucially on the legal, political, economic, and cultural context, that is, the specific social system being regulated. To better understand the context-specificity of climate-related regulation, in-depth analyses are required to assess it as a driver. For that reason, the observations (see below) in this first *Outlook* provide only a brief overview of developments in the four highest emitting countries—China, the United States (US), the European Union (EU), and India—and then turn to a more detailed analysis of driver dynamics in the EU, using Germany as an example. Both, the EU and Germany are often perceived as climate frontrunners, as examples of a jurisdiction or state with the potential to fulfill the necessary requirements to follow a path of deep decarbonization. Although no member state of the

EU alone may have a significant impact on deep decarbonization, the possible contribution of the EU can only be analyzed by taking the member-state level into account, too. In examining both the EU and its member states, it is crucial to understand the dynamics of multi-level climate-related regulation. Any assessment of possible enabling and constraining conditions must acknowledge the (dys)functionalities of climate-related regulation and its role as a driver toward deep decarbonization, as well as the interlinkages, synergies, and trade-offs between the different levels of regulation.

Constitutional principles—including the rule of law, the principle of proportionality, federalism and other organizational principles to diffuse state power, constitutional values, and fundamental rights and interests—compete with the goal to protect the climate and can act as constraints. These principles can, however, also enable climate-related regulation, such as when climate protection is acknowledged as a state goal (Wickel, 2020: 157). In multilevel political systems, the same effect arises from regulation on higher levels, such as in the relationship between the EU and the member states. Climate litigation can also enable or constrain ambitious climate-related regulation and its implementation.

Another crucial enabling or constraining condition for climate-related regulation in a democratic state are political majorities. They in turn are significantly shaped by economic conditions and actors, social movements, media, and (scientific) knowledge. Furthermore, the state of technology determines what is possible and how much it costs to achieve specific targets. Technological development is itself partly determined by climate-related regulation, which sets compliance standards and influences investments in research and development (Newell et al., 1999; Acemoglu et al., 2012; Aghion et al., 2016). Moreover, cultural technology affinity or aversion are relevant enabling and constraining conditions (Rothwell and Wissema, 1986; Emmerich et al., 2020).

UN climate governance and the Paris Agreement obliges the to-date 190 state parties to participate in a legally binding pledge and review mechanism and to each submit Nationally Determined Contributions (NDCs) (Section 8.1). These NDCs are not legally binding as such and state parties are free to determine their level of contribution, but the NDCs still act as an important link between the overall “well below 2°C” target of the Paris Agreement and national climate-related regulation targets and instruments. Corporate responses and fossil fuel divestments (Sections 8.6 and 8.7) are shaped by climate-related regulation but companies’ strategies also are a decisive enabling or constraining condition for regulation. Climate protests and social movements (Section 8.4) significantly shape the social and political conditions of the making, implementation, and enforcement of regulation. The number of climate litigation cases has been constantly rising in the last two decades and is expected to rise further, supported by

a growing body of climate-related regulation and strategic litigation networks (Section 8.5). Most of these cases are directed against governments and companies and aim to push for more ambitious target setting and regulation or corporate liability. Finally, climate-related regulation develops in the context of and is shaped by manifold expert advice and knowledge production (Section 8.10).

Observations

Numerous initiatives have begun to track domestic climate-related regulations and NDCs, sparked in particular by the adoption of the Paris Agreement. Such initiatives are led by a wide range of stakeholders, including international organizations, research institutions, and NGOs. They cover a wide range of methodological approaches, from predominantly qualitative assessments and projections (Moisio et al., 2020; UNEP, 2020a) to quantitative databases (GRI and LSE, 2020) and ranking schemes like CCPI (CCPI, n.d.). These initiatives also differ in scope, such as whether they include adaptation in their analysis, or focus on specific aspects of climate-related regulation like the ECIU scorecard (ECIU, n.d.). All of these approaches have their limitations and strengths, which must be considered before drawing conclusions about overall regulatory trends.

The UNEP Emissions Gap Report is a widely recognized product authored by an “international team consisting of 51 leading scientists from 35 expert institutions across 18 countries” (UNEP, 2020a: 2). Since 2010, the report has annually examined the ambition gap between established climate policies and the global temperature targets agreed under the UNFCCC. The report tracks how the gap between ambition and actual climate policies continues to widen, and provides insightful systematic analysis of each of the G20 countries. According to the UNEP Emissions Gap Report, the G20 countries emit about 78% of global emissions, and are not on track to achieve their NDC commitments provided under the Paris Agreement. Given that the NDCs as they stand are considered “seriously inadequate” to achieve the temperature goals set in the Paris Agreement (UNEP, 2020a: XXI), there appears to be a significant ambition gap between ambitious long-term targets pledged at the multilateral level and the actual progress in domestic climate-related regulation.

Our assessment can only provide a snapshot of current trends in climate-related regulation, especially since the political environment in many G20 countries is rapidly changing and the global crisis of the COVID-19 pandemic creates considerable uncertainty. However, we do observe that the overall trajectory of actually implemented and legally binding climate-related regulation in high-emitting countries has so far been insufficient to legally operationalize a transition to deep decarbonization. The four highest emitting countries, China, the United States, the EU, and India, are politically highly relevant and illustrative examples of this:

- ▶ In China, the recent political announcement of peak emissions by 2030 and to achieve carbon neutrality before 2060 (UNEP, 2020a: 19) is one of the most notable examples of national goals being brought more in line with deep decarbonization. At the same time, its continuing support for the coal industry, both domestically and abroad undermines these efforts (UNEP, 2020a: 19; CAT, n.d.). The 5-year plan released in March 2021 (Hepburn et al., 2021) provides more insights on climate-related regulation, specifically on whether, and if so how, the 2030 and 2060 pledges will be operationalized in actual regulations, but the plan could not be assessed in time for this publication. To date, there is still a considerable gap between the commitments and the regulations that have been implemented (CAT, n.d.).
- ▶ The European Union (EU) submitted its new NDC in December 2020 and thereby communicated its new 2030 target of -55% and the long-term target of net-zero greenhouse gas emissions by 2050 (EU NDC, 2020). Although the EU's emissions are decreasing, and although the EU and some of its member states are often perceived as climate frontrunners, political struggles around the new targets and their implementation in climate-related regulation, both at the Union and member-state level, indicate challenges for climate-related regulation consistent with deep decarbonization (Geden and Schenuit, 2019 and see detailed analysis below).
- ▶ India did not yet announce a net-zero long-term target and a peak of emissions has not yet materialized. Based on considering equity assumptions in their assessment, the Climate Action Tracker ranks India's efforts as being "in line with 2°C", but highlights that the current policies and targets are not consistent with the Paris Agreement. In particular, the plans for expanding coal-fired power generation (UNEP, 2020a: 19) indicate that current regulations are not consistent with deep decarbonization (see also IEA, 2021b; IEA, 2021a).
- ▶ In the United States, the election of the new Biden and Harris administration in 2020 reversed the approach to climate policy of the previous administration. The re-entering to the Paris Agreement and first initiatives clearly indicate a shift toward significantly more ambitious climate-related regulation, including the adoption of a net-zero target. However, only the coming years will show whether the government is capable of operationalizing and translating its pledge of achieving net-zero emissions by 2050 into legally binding emissions-reduction policies (Bodansky, 2021).

These brief insights on the highest-emitting countries illustrate the gap between long-term targets and actionable climate-related regulation in context. Birds-eye assessments and rankings do not provide enough insights into the (dys)functionality of established climate policy mixes. To explore plausible prospects of climate regulation as a driver toward deep decarbonization, societal, political, and regulatory contexts need to be considered. Exploring the degree to which the long-term goal of deep decarbonization is already effectively operationalized in climate-related regulation can be best studied in a case that is often assessed to be a climate frontrunner. The following in-depth analysis of the situation in the EU and Germany as one of its member states shows that even climate-related regulation by declared climate frontrunners incorporate dysfunctions that run the risk of damaging the effectiveness of the regulations in achieving climate objectives.

European Union (EU)

Given the scope and diversity of climate-related regulation and the relevant conditions, it is reasonable to start investigating climate-related regulation within the boundaries of a specific, yet insightful case. We select the EU, because it has well-defined targets set in its 2030 Climate and Energy Framework:

- ▶ 40% cuts in greenhouse gas emissions from 1990 levels by 2030 (this is in the process of being raised to 55%, including for the first time removals by sinks as well).
- ▶ 32% renewable energy in final energy consumption by 2030 (Art. 3 Directive 2018/2001/EU).
- ▶ 32.5% improvement in energy efficiency by 2030 relative to the 2007 modeling projections for 2030 (Art. 1 Directive 2012/27/EU).

The net-zero emissions target by 2050 is set with the European Climate Law. Hence, formally, the EU is in line with the deep decarbonization scenario if one compares it to the global average target of achieving net-zero by mid-century. The latter, however, can be disputed on grounds of international climate justice. If the remaining global carbon budget is distributed to jurisdictions based on equity criteria, the EU would need to reach net-zero much earlier (see e.g., van den Berg et al., 2020).

A large array of instruments has been introduced with reference to the above targets. We focus on the key instruments that have been implemented with specific reference to greenhouse gas emissions and present key insights from the recent scientific literature on whether their stringency, design and coherence makes achievement of the targets plausible. Because the EU is still in the process of adjusting its climate policy mix to the newly ambitious targets, we will mainly focus on conceptual aspects that affect the effectiveness of instrument mixes to reduce greenhouse gas emissions.

The EU Emissions Trading System

The EU Emissions Trading System (EU ETS) is the cornerstone of the EU's climate policy. It operates in all EU countries plus Iceland, Liechtenstein and Norway, and limits emissions from more than 11,000 heavy energy-using installations (power stations & industrial plants) and airlines operating between these countries. It covers around 39% of the EU's greenhouse gas emissions (European Commission, 2019b) including those of the power sector, steel, aluminum, pulp and paper, chemical plants, and inner-EU flights.

The example of the EU ETS highlights the importance of interactions with other instruments in the broader regulatory context, in particular those aiming at the technology mix in electricity production, such as renewable support schemes and coal phase-outs, reductions in electricity demand (e.g., energy efficiency measures) and substitution of fossil fuels by electricity (Power-to-X, green hydrogen). We therefore zoom in on this particular instrument to highlight a much more general principle in climate-related regulation, namely that design details and regulatory context matter for the actual impact on emissions reductions of specific instruments and instrument mixes. It is this actual impact that counts when assessing whether climate-related regulation is on track for achieving the targets set by the EU.

The EU ETS works on the cap-and-trade principle. A cap is set on the total amount of certain greenhouse gases emitted by installations covered by the system. The cap decreases over time in line with the EU's greenhouse gas emissions targets. After a reform in 2018 EU ETS, sectors need to reduce their emissions by 43% relative to 2005 and the last allowance would be issued in 2057, but a further reform is under way, triggered by the newly increased EU climate targets. The reform in 2018 made the long-run cap on emissions an explicit function of market outcomes for the first time. This means that the policy-maker has implemented a contingent rule that adjusts the emissions target based on current and future dynamics of the regulated system (Perino, 2018). Trading introduces flexibility, which ensures emissions are cut where it costs least to do so. A robust carbon price promotes investment in low-carbon technologies (Calel and Dechezleprêtre, 2016; Teixidó et al., 2019).

Assessments of past performance have been mixed (Geels et al., 2017; Dechezleprêtre et al., 2018; Fuss et al., 2018a; Bayer and Aklın, 2020; Best et al., 2020; Green, 2021). In the first decade, prices were mostly below expectations and too low to drive the low-carbon transition in any significant way. In response to increased ambition and the design changes introduced by the 2018 reform, allowance prices roughly tripled by 2019. Despite this success, the new design introduced adverse interactions with overlapping policies (Rosendahl, 2019) and high complexity (Perino, 2018; Wettstad and Jevnaker, 2019). The mechanism that makes the cap

respond to market outcomes, the market stability reserve, is ill-designed. While the mechanism works roughly as intended for unanticipated short-term events, such as the COVID-19 pandemic (Gerlagh et al., 2020), it creates substantial uncertainty over total emissions in the long-run (Bruninx et al., 2020) and tends to do exactly the opposite of what is desirable for anticipated future events. For example, climate policies which overlap with the EU ETS such as coal phase-outs and renewable support schemes may reduce future demand for allowances, which can lead to an increase in total emissions within the EU ETS (Perino et al., 2019; Rosendahl, 2019; Gerlagh et al., 2021).

The market stability reserve also undermines voluntary cancellations by member states, which are intended to strengthen the emissions impact of overlapping policy in accordance with the provision in Art. 12(4) of the EU ETS Directive 2003/87/EC (Gerlagh and Heijmans, 2019), even though this provision was introduced in the same amendment as the market stability reserve. These policies therefore undermine their joint emissions impact due to subtle design features. The future scope, stringency and design of the EU ETS will be a decisive factor for whether the EU will achieve its abatement targets for 2030 and 2050.

Climate policies which overlap with the EU ETS can also have spillover or leakage effects to those sectors covered by the Effort Sharing Regulation (see p 85). Renewable energy support (Jarke and Perino, 2017), sector-coupling (Jarke-Neuert and Perino, 2019), energy efficiency policies (Perino and Pioch, 2017; Jarke-Neuert and Perino, 2020), and voluntary climate action campaigns (Perino, 2015) that target EU ETS industries can both increase and decrease greenhouse gas emissions in non-EU ETS sectors. In the case of renewable support schemes, the way in which funds for subsidies are raised can determine whether the policy increases or decreases total emissions (Jarke and Perino, 2017).

Looking at an instrument in isolation is a highly unreliable indicator of its effectiveness in a particular regulatory context. The EU, its member states, and many other jurisdictions still lack effective governance mechanisms that would ensure internal consistency of their climate policy mixes. The European Commission's impact assessment on the implementation of the recently increased ambitions (European Commission, 2020) does not appear to fix this shortcoming (Knodt et al., 2020).

In September 2020, the Commission presented an impact-assessed plan (European Commission, 2020) to increase the EU's greenhouse gas emissions reduction target to at least 55% by 2030, as part of the new European Green Deal. By June 2021, the Commission will present legislative proposals to implement the new target, including revising and possibly expanding the EU ETS. The EU ETS is a powerful tool that combines political control over cumulative emissions with the potential for an efficient transition path. While recent reforms have

started to address the lack of ambition, they have decreased coherence with other climate and energy policies and thereby created a risk for the effectiveness of the wider climate policy mix. The upcoming adjustments should aim at bringing it in line with the new EU targets and substantially improve its ability to create synergies with overlapping policies.

Regulation on Effort Sharing

Regulation on Effort Sharing establishes binding annual greenhouse gas emissions targets for member states for the periods 2013–2020 (Decision No 406/2009/EC) and 2021–2030 (Regulation (EU) 2018/842). These targets concern emissions from most sectors not included in the EU ETS, such as transport, buildings, agriculture, and waste. National targets sum up to a 10% reduction in emissions for the sectors covered by 2020 and 30% by 2030 relative to 2005 levels.

Effort Sharing can be seen as an example for regulation in a multilevel system. In contrast to sectors in the EU ETS, which are regulated at EU level, member states are responsible to limit emissions from the sectors covered by the Effort Sharing legislation. Therefore, the member states have to enact regulation themselves. The EU, however, provides for some instruments to be implemented on national level, such as integrated energy and climate plans, and long-term strategies (Regulation (EU) 2018/1999).

An example for national legislation within this European system is the German Federal Climate Protection Act of 2019. It provides for a reduction pathway and a greenhouse gas emissions reduction of at least 55% in 2030 (compared to 1990) as an intermediate goal on this pathway. The Act declares deep decarbonization as a general goal for 2050. The Act also refers to the long-term strategy as a planning instrument and provides for a climate program that describes the necessary measures to reach the climate protection targets. Further instruments provided for by the act include annual reports and auditing by an independent expert council.

The federal structure requires climate-related regulation to be implemented by the federal states as well. In 2013, the federal states started to enact Climate Protection Acts (Wickel, 2019: 1). At the time of writing, ten of these Acts exist on state level. They set greenhouse gas emissions reduction goals and most of them formally create a planning instrument to frame the necessary measures. In most cases they replace already existing informal policies and thereby establish a stronger legally-binding effect. In Germany, the number of Climate Protection Acts indicates that this driver is pushing in the direction of decarbonization on the national level. This is also supported by the fact that the more recent Climate Protection Acts set targets that are more closely aligned with deep decarbonization by 2050.

Observed changes in constraining and enabling conditions

When the higher levels of a multilevel system impose new binding targets, this can cause changes in the (structural) enabling and constraining conditions of the climate-related regulation driver. The intention to raise the greenhouse gas emissions reduction target on EU level will have a direct impact on regulation in member states. Another change that can be observed, although not widespread, is the new constitutional provisions embracing climate protection as a constitutional goal.

An illustrative example of how observed changes in enabling and constraining conditions shape climate-related regulation is the *IPCC Special Report on Global Warming of 1.5°C* (see Section 8.10). It met with rising concern among young people, which culminated in millions of protesters attending the global climate strikes in 2019 (see Section 8.4). This had a substantial impact on the elections for the European Parliament in 2019, which is now torn between strong green and strong anti-EU/anti-climate-protection fractions. This dynamic also contributed to a new European Commission, which made climate policy a prime objective.

In Germany, the increased public concern for climate protection has been received by established parliamentary majorities. While it clearly sparked new regulatory initiatives, such as the introduction of a carbon pricing scheme in the heating and transport sector, the ambition of the government's climate package remained well behind protesters' expectations and appears not to be sufficient to reach the government's own targets (UBA, 2019; UBA, 2020a).

Bifurcations

2021 and 2022 could become important years for a bifurcation at EU level. The new targets with the target of *net-zero by 2050* are broadly in line with the deep decarbonization scenario considered here. The key question is whether the combination, design, and stringency of policies chosen will be suitable to implement them. In 2021 and 2022, the EU will lay the groundwork by determining key components of the instrument mix. The expansion and reform of the EU ETS, the scope of Union-wide and national instruments, and the role of specific targets for renewable expansion and energy efficiency will be determined. The following years will reveal how member states respond to this framework.

COVID-19

Recent climate-related regulation in the EU was passed prior to the COVID-19 pandemic. However, the implementation of passed legislation as well as new legislation is and will be affected by the pandemic. While it may enable a climate-friendly restart (Amelang et al., 2020), it may also slow down or hinder climate-related regulation due to new political and societal priorities, reallocation of funds to economic and health sectors, and limitations on

climate protests. The design and ambition of fiscal stimulus packages and climate policy will be crucial for the medium- to long-term impact of the pandemic on the plausibility of deep decarbonization (Barbier, 2020; Engstrom et al., 2020; Lahcen et al., 2020; Mukanjari and Sterner, 2020; see also Box 4).

Looking forward

Climate-related regulation will remain a decisive driver in decarbonizing the economy. The birds-eye perspective on the largest emitters together with a more fine-grained analysis of developments in climate-related regulation in the EU clearly showed that existing climate-related regulation in these countries is not sufficient to support deep decarbonization. The COVID-19 pandemic long-term impacts on climate-related regulation are yet unclear. The recent elections in the US and the stepping up of ambitions in China and the EU indicate that support for decarbonization might increase over the next five years. However, it remains to be seen whether ambitions translate into effective and coherent regulatory frameworks.

This poses a substantial challenge for climate-related regulation. The developments over the next five years are absolutely critical for aligning the emissions trajectory with targets that are consistent with the deep decarbonization scenario. This is especially true for the EU, as the design of climate-related regulation and the inscribed level of legally binding climate ambition will decide whether the EU and its member states can live up to their targets. So far, we observe a substantial gap between the objective of net-zero emissions and the stringency and coherence of instruments applied to achieve them. Deep decarbonization can only be reached if this gap can be narrowed, and if the current pace of greenhouse gas emissions abatement is accelerated substantially, making residual emissions in 2050 as low as possible. In Europe's largest economy, Germany, recently enacted measures, such as the coal phase-out, renewable deployment, and the carbon pricing mechanism in the heating and transport sectors have been evaluated as insufficient to reach the 2030 goal, which is still based on the less ambitious EU targets set in 2014 (UBA, 2020a).

This is also true for other large emitters. The way long-term ambitions are being operationalized into short-term, actionable climate-related regulation will shape the plausibility and eventually even the possibility of achieving deep decarbonization. Substantially higher ambition is needed, not only in new targets, but also in the design and implementation of legal instruments. Developing and maintaining respective momentum against the current shift in public attention, priorities, and funds related to the COVID-19 pandemic will be difficult. However, the pandemic also creates a window of opportunity that might accelerate the transition if targeted public support and climate policies such as

carbon pricing induce a green restart of worldwide economies (see Box 4).

The bottom line is: Despite the substantial dynamic observed in 2019 and 2020, climate-related regulation is not yet on track. We therefore conclude that climate-related regulation is currently not on track to support deep decarbonization by 2050. Sufficient political support, in particular over the next five years, and further technological progress are crucial for the implementation of climate regulation consistent with deep decarbonization. The processes behind the formation of political support will differ substantially across jurisdictions, but other drivers including climate protest and social movements, UN climate governance, climate litigation, and knowledge production are likely to be highly relevant.

Resources generated by this driver

Regulatory approaches and innovations are discussed internationally both in scientific and policy circles. Hence, innovative approaches and experiences with different instruments contribute to the global stock of knowledge resulting in an increasing diversification in the international climate policy discourse over time (Meckling and Allan, 2020). Our analysis shows that climate-related regulation has the potential to provide relevant resources for a global opportunity structure in a deep decarbonization scenario. Not only in translating long-term pledges into actionable legislation, but also more concretely with regard to certain business practices or lifestyles, for example through regulating fossil fuel use, mobility choices, energy supply from renewable sources, or energy efficiency.

Another relevant resource provided by this driver is the diffusion of national policy designs that are perceived as successful to other nation states. For example, the German Energy Transition, itself a potpourri of different instruments, has been regarded as a litmus test of whether such an ambitious transition is feasible. Despite the mixed perception domestically, lessons have been drawn from the German experience (Cheung et al., 2019; Rechsteiner, 2021) and it has become a role model for similar endeavors in very different parts of the world (Antal and Karhunmaa, 2018; Schiffer and Trüby, 2018; Valdes et al., 2019). There is emerging evidence that the German Energy Transition has become an instrument of soft power and that the German government actively promotes adoption of its policy solutions by other countries (Quitow and Thielges, 2020). However, as has been pointed out above, context matters for instrument effectiveness. Hence, instruments that might drive a society toward deep decarbonization in one country might yield rather different effects in another; an important fact to consider when assessing the plausibility of a deep decarbonization scenario.

8.4

Climate protests and social movements

Driver description

Climate protests and social movements refers to climate-related political activism and grassroots mobilization, which contribute to the public exchange of arguments and climate change discourses. Social movements create new and change existing social dynamics by connecting collective action and politics through practices of contention. Contention involves “interactions in which actors make claims bearing on someone else’s interests, in which governments appear either as targets, initiators of claims, or third parties” (Tilly, 2008: 5). The concept of social movement narrows the scale and context to particular collective practices of contention that can be distinguished from other “collective phenomena” (Melucci, 1989: 21). Collective action, which can be defined as “coordinating efforts on behalf of shared interests or programs” (Tilly, 2008: 6) is a regular aspect of social life and often a routine. Contention and collective action enter the realm of politics when actors make claims toward governments, existing regulations, and institutions. This driver focuses for analytical reasons only on the limited set of “claim-making performances” of social movements (Tilly, 2008); it therefore does not encompass the numerous other contentious practices that may also shape dynamics toward deep decarbonization. In general terms, climate protests and social movements seek to frame climate change as a collective problem requiring social and political change to achieve deep decarbonization. These claim-making practices involve conflicts of interest and norm contestations on different scales of politics. Climate-related protests and claim-making processes as well as the expressions of competing interests are put forward, contested, and weighed, both within and outside of established political institutions (Mueller, 1997; Tarrow and Tilly, 2009; Farber and O’Connell, 2010). In this process, views and arguments about climate change and different courses of climate action (and non-action) are exchanged, thereby influencing preferences and beliefs, which in turn influence individual and collective decision-making (Brekke and Johansson-Stenman, 2008; Gintis, 2009), including consumption, investment and abatement choices, technology adoption, voting in elections, and public policy. As such, this driver fundamentally shapes the velocity of change required for the deep decarbonization scenario.

Hence, involved actors seek to gain direct access to decision-making processes in the context of climate policies, and to contest and change existing dynamics toward deep decarbonization by shifting perceptions, narratives, and discourses about how to tackle climate change. In particular, collective action introduces new ways of understanding the past and present as well as possible climate futures. Such political “stories” can help actors form alliances, affect policy change (Hajer, 1995; Viehöver, 2014), or build new social norms (Spaiser and Stefan, 2020). The power of non-state political actors is thus often seen as a moral power and related to discourse; it influences the dominant assessment of “what can be said, felt and thought” (politically) (Bröer and Duyvendak, 2009: 339). Narratives are seen as a key component of movements themselves (Della Porta et al., 2015a). By framing an issue in different ways, power-holders and dominant policies can be (de-)legitimized. Perhaps as critical as the particular narrative framing is the author of the framing and whether the framing appeals to the emotions of the public. For example, in the case of the young climate activist Greta Thunberg and the Fridays for Future movement, an alternative political narrative has been forged that delegitimizes business-as-usual climate policy and emotionally anchors this political climate in the abandonment of future generations.

While protests are often the most visible form of collective action, social movements contest dominant orders in a variety of ways. Movements attempt to enact bottom-up change via local experiments, such as the establishment of climate neutral villages or Transition Town Networks (Bendix, 2017). These actions tend to be small in scale, and it is not always clear whether the implementation on larger scales is possible (de Moor et al., 2019; Blühdorn and Deflorian, 2021). Yet these actions allow movements to contextualize issues that are often perceived as local within the global issues of climate change and environmental degradation, which unfolds on larger political and economic scales. Protests and contentious politics appear in diverse ways, depending on the political and cultural context and therefore vary in terms of repertoire, mobilization, or organization (Tilly, 2008). In authoritarian or (post-)war states, climate and environmental activism unfold in very different ways. Street protests—a central repertoire of claim-making for example in Europe and North America—do not constitute the universal standard mode of protesting. Specific forms of protest, such as so-called *quiet encroachment* (Bayat, 2010), may

not only resonate more within given settings, but also prove to be more effective. Since activists in the Global South observed and felt the consequences of climate change long before it became a broader issue in Europe and the United States, diverse forms of protests, mobilization efforts, and claims exist. Movements in the Global South have criticized the fact that climate change is often framed merely as a technical issue, and have instead successfully claimed that climate change is linked to social, economic, and political problems (Gilio-Whitaker, 2019).

Climate movements claim that solutions to climate change can only be implemented by addressing multiple issue areas, including consumption patterns, investment and abatement choices, technology adoption, voting in elections, and public policy. For example, highly visible climate activist movements (Fridays for Future; Haunss and Sommer, 2020), environmental NGOs, and green parties create momentum toward deep decarbonization, which is countered by opposing momentum from fossil fuel industry associations, climate change denial think tanks (Cann and Raymond, 2018; Fischer, 2019), high-carbon lifestyle activists (Fridays for *Hubraum*), and right-wing parties. Further key players include trade unions, indigenous movements, rural associations, and other civil society actors.

Constraining and enabling conditions for climate protests and social movements

There is a range of political, technological, and cultural conditions that shape and affect the dynamics of climate protests and social movements. This driver can have substantial influence if democratic and transparent political institutions prevail alongside constitutional conditions that guarantee the free exchange of information and freedom of association. However, this does not imply a direct dynamic toward deep decarbonization. In local contexts, there can be a consensus that climate change is not a priority under the given socio-economic conditions. Conversely, clarifying the consequences of different courses of climate action, polarization and deadlock can result in societies with highly diverse interests. Thus, another critical feature of the driver is the capacity to resolve conflict. Furthermore, even if certain enabling conditions for the driver are present, political actors must first be able to recognize these conditions as opportunities before they can take advantage of them. The driver can gain increasing momentum when its topic and claims create resonance with the public and more legitimized actors, such as when recognized scientists and media supported (and in some cases criticized) Fridays for Future, paving the way for strikes in secondary schools (Statham and Koopmans, 1999; Koopmans and Olzak, 2004; Duyvendak and Bröer, 2009). Therefore, the perceived chances of political actors as well as their past experiences with successes or failures influence their strategizing and can produce self-enhancing effects (de Moor and Wahlström, 2019).

The driver's effect is also moderated by the state of technology and access to specific technologies (Tufekci and Wilson, 2012). An apparent example is digitalization, including the internet and related hardware and software, which dramatically amplifies the social capacity to collect, process, and exchange information, and to coordinate actions such as protest events (Bakshy et al., 2012; Guille et al., 2013; Boulianne et al., 2020). The state of technology also shapes the relative costs of different courses of climate action, and hence the pattern of interests represented within the driver. Cultural traits can also shape the driver directly (such as by informal norms of discourse), and indirectly through the institutional and technological conditions (such as when a culture of technology affinity or aversion drives the de facto state of technology).

In the following section we summarize current literature and our own ongoing field research, in order to provide some insight into the diversity of spatial and temporal contexts in which the driver shapes dynamics toward or away from deep decarbonization.

Observations

The topic of climate change received increased attention in national policy debates (Sommer et al., 2019; Wahlström et al., 2019), with global climate strikes bringing millions of people onto the streets (Barclay and Resnick, 2019; Gerretsen, 2019; Laville and Watts, 2019), before suffering from a recent drop in interest with the COVID-19 pandemic. Nevertheless, in some countries, climate change has received continued interest and attention (Schlandt, 2020). Social movements in the Global South are facing additional challenges with regard to organizing collective action due to the pandemic, as national governments incorporate measures against COVID-19 into their strategies to stop protests (see for example the HIRAK Movement in Algeria: Davis and Kasmi, 2020). Thus, an analysis of current changes of the driver's dynamics and an assessment of the impact of potential future dynamics on the deep decarbonization scenario are very difficult to conduct. The COVID-19 pandemic has temporarily disrupted climate protests due to public assembly restrictions. It also shifted the public and political focus, and moved the discourse from the streets into formal political institutions (for example in terms of the "greenness" of the recovery packages). It is therefore currently difficult to assess in what direction the driver is developing. It is possible that there are benefits gained from the societal experience with the pandemic, since it has helped highlight the importance of science and cooperation (Corry and Reiner, 2020). Furthermore, social movements are actively seeking to adapt to the situation and to focus on other repertoires, such as strategic litigation (see Section 8.5).

In general, support from other, more socially-recognized public actors in the fields of media or science can enhance the alternative future visions put

forward by movements in national policy debates. However, the relationship between social movements and scientific actors can also be problematic. Some fractions of the climate movement ascribe to the technocratic idea that right policies can be derived directly from “the science”. Such claims for scientific legitimacy could harm the public debate if non-negotiable, scientific standpoints leave little room for ethical and moral considerations or other forms of dissent, providing impetus for strong counter-movements (Franz et al., 2019; Blühdorn and Deflorian, 2021). Such a public divide can already be observed in the United States (Gustafson et al., 2019; Blühdorn and Deflorian, 2021). Other actors in the United States, such as conservative think tanks, have switched from using *uncertainty frames* regarding climate change toward more actively calling into question scientific results and scientific authority (Cann and Raymond, 2018).

Furthermore, there are additional considerations that make the potential impact of current climate protests uncertain. While some argue that Fridays for Future is not radical enough (Sommer et al., 2019), others criticize Extinction Rebellion for being apocalyptic, triggering a sense of hopelessness (Cascio, 2019; Osaka, 2019), or for reproducing Eurocentric climate future narratives (Rothe, 2019). Some claim that positive future visions are essential for triggering discursive change, allowing more ambitious future scenarios of decarbonization to elicit policy-relevant reactions (Strunz et al., 2019). The impact of protests and social movements is therefore influenced not only by the discursive relevance of their claims, but also the content and the political visions ascribed to their claims. Moreover, it is important to consider the potentially diverse and possibly contradictory role of activists, who may either seek a position in political institutions or tend to “professionalize” and in the process lose their “revolutionary” tendencies, as is the case for many environmental NGOs like Greenpeace, Friends of the Earth and WWF, and for the Green party in Germany (Switek, 2015; Sperfeld et al., 2017: 3-5). In the case of Fridays for Future Germany, one can already witness such tendencies, with some activists aiming for political mandates (Zaremba, 2020).

One should also be aware that current climate activism is grounded on decade-long traditions of activism, with the newest iterations marking a return to the state after the climate movements withdrew their confidence in international politics after COP15 in Copenhagen (de Moor et al., 2020; Blühdorn and Deflorian, 2021). Greta Thunberg, Extinction Rebellion, and Fridays for Future have built upon action from the environmental movement of previous decades, be it NGOs like Greenpeace, the Climate Justice Action Network (Harlan et al., 2015; de Moor and Wahlström, 2019), or the Divestment movement (Gunningham, 2017a: 372-373; Bergman, 2018) of recent years. On the other hand, climate denialism also offers a narrative, which gained salience in the US-American public discourse and

elsewhere over the last years, feeding into a sense of public distrust and further divide (Cann and Raymond, 2018; Lejano and Nero, 2020). Over the course of the next years, whether or not the new climate movements can alter public and political perception of climate change will depend on multiple external and internal factors.

At the same time, different strategies of climate protests are running in parallel, including experimentation in alternative, more sustainable practices (Blühdorn and Deflorian, 2021: 11). This could be possibly influencing municipalities or local businesses, although financial limits often hamper the immediate success of such bottom-up initiatives (de Moor et al., 2019). Others engage primarily in protest action and political campaigning. While the Sunrise movement in the United States actively supports institutional politics by backing the Green New Deal resolution (Nwanevu, 2019; Hathaway, 2020), Extinction Rebellion in Germany criticizes parliamentary democracy and instead advocates for a *citizen assembly*, having proposed it to the Bundestag in the beginning of 2021.

A growing number of activists is further engaged in cross-fertilizing activities with academia and intellectuals, developing and advocating for future visions like *degrowth*, *post-development*, or *deep decarbonization*, visions which could disseminate into broader publics over time, but have not reached mainstream relevance yet (Jamison, 2010; Kallis et al., 2016; Bendix, 2017). Of further relevance is the notion of climate justice, combining a post-colonial and social justice perspective with the issue of climate change, in the United States, but also in international, non-western perspectives, as seen with the *buen vivir* concept in Latin America (Harlan et al., 2015; Acosta and Brand, 2018).

Looking forward

In summary, climate protests and social movements have a long history of influencing political and public perception of the climate topic and other environmental issues. Even before movements like Fridays for Future raised the issue in public debates in 2019 and 2020, climate protests had influenced the overall debate on the best environmental and climate policy trajectory through various practices—on a small scale, in national public arenas as well as in international negotiations. However, we identify a further rise in salience, which was not primarily triggered by international negotiations (such as Copenhagen 2009 or Paris 2015) or catastrophic events, but instead by protest action centered around narratives of generational justice and the state’s responsibility to act. Depending on how climate movements perceive their opportunities and how high the salience of the topic is (topic institutionalization), more ambitious future visions and politics could begin to gain ground in public discourse. Fridays for Future and Extinction Rebellion both have supported concepts like *degrowth*, *climate justice*, or *circular*

economy (Fridays for Future Deutschland, 2019; Extinction Rebellion Deutschland, 2020), but did not make these concepts central to their message. The COVID-19 pandemic could increase faith in comprehensive state action during times of crisis, thus inducing movements to advocate for more state action and a shift toward more regulative policies.

However, any extreme weather event, any scientific or technological breakthrough, or any major political disruption could push the dynamics toward another trajectory, as seen with Green party support in Germany in recent years. It is also uncertain as to whether the drop in interest in the climate topic follows issue-interest cycles seen with other policy issues, or whether the issue will rise again to the highest level of political relevance after the COVID-19 crisis. Furthermore, it is unclear if political pressure by the movements can be upheld in the wake of the upcoming national elections as well as the next COPs.

Resources generated by this driver

Climate protests and social movements still occupy a central position in worldwide climate debates and provide other social drivers of decarbonization with a series of resources for ambitious climate action. In particular, the driver provides societal actors with a series of ideas, norms, and visions (Della Porta et

al., 2015a: 534; Spaiser and Stefan, 2020), which can trigger (dis-)identification with and re-interpretation of the dominant societal discourse or lifestyle choices, and increase the potential for behavioral change (Schifeling and Hoffman, 2017: 213; de Moor and Wahlström, 2019: 425-426; Smith and Bognar, 2019: 1-5). Simulation and appropriation practices provide resources like local production networks and chances for social identification (de Moor et al., 2019: 2-5; Blühdorn and Deflorian, 2021: 6-8). Via communicative action and protests, the driver generates media attention, has an influence on setting the public agenda and creates public pressure through campaigning. This public pressure has an effect on firms or public institutes to divest from fossil fuels (Gunningham, 2017a; Bergman, 2018). In the past, environmental movements have often developed into more organized forms of civil society, such as NGOs, which can act as expert stakeholders (Della Porta et al., 2015b: 736). In the case of climate litigation, specialized climate NGOs are providing legal advice or can act as plaintiffs (UNEP, 2020b). Strong protests directed at corporate responses to climate change and at institutional investors can increase the pressure on these private actors as well. Climate protests and social movements could thus strengthen the different drivers covered in our plausibility assessment in very direct ways.

8.5

Climate litigation

Driver description

Over the last two decades, a growing number of lawsuits has been initiated against governments, administrations or companies to strengthen national emissions reduction commitments, prevent carbon-intensive infrastructure projects, or hold firms accountable for warming impacts (Burns and Osofsky, 2009; UNEP, 2017; Setzer and Vanhala, 2019; Eskander et al., 2020; Setzer and Byrnes, 2020). Based on experiences in other fields, such as civil and human rights, it is commonly assumed that such lawsuits could catalyze more ambitious climate action (Esrin and Kennedy, 2014; Boom et al., 2017; Fisher et al., 2017; Huglo, 2018).

Most climate lawsuits take place before national courts. As of October 2020, the two key databases collecting national climate change cases count about 1400 climate lawsuits in the United States and about 400 cases in the rest of the world, most of the latter in Australia (113), the United Kingdom (64) and the European Union (55) (GRI and LSE,

2020; Sabin Center for Climate Change Law and Arnold & Porter, 2020). These databases are not complete, especially for cases outside the United States, and they adopt a rather broad definition of *climate litigation*, covering strategic and individual cases as well as cases that support and counteract climate change mitigation efforts. For example, the LSE/Grantham Institute database collects all cases that “raise issues of law or fact regarding the science of climate change and/or climate change mitigation and adaptation policies or efforts before an administrative, judicial or other investigatory body” (GRI and LSE, 2020). Setzer and Byrnes (2020: 6) find that up until May 2020, climate change was at the center of the legal argument in 41% of these cases, whereas in 59% it plays a peripheral role and the legal argument is grounded, for example, in air pollution or forest protection instead. Conversely, we chose to adopt a narrow definition of *climate lawsuits* in this first stage of research, including only (strategic or individual) cases intended “in favor of” decarbonization and climate justice. This leaves aside,

among others, lawsuits intended by firms and other legal entities “against” climate legislation (such as the coal phase-out), litigation against renewable energy projects following the repudiating logic of not-in-my-backyard, WTO and investment disputes related to renewable energies. Far greater in terms of absolute numbers, these lawsuits constrain ambitious climate policy and can have a *chilling effect* on regulation, implementation, enforcement, and investments. While important in the overall context of deep decarbonization, such lawsuits do not contribute to the dynamics of the more specific, social process of climate litigation as defined here.

For analytical purposes, it is important to note that climate lawsuits often combine legal objectives and more explicitly political as well as broader societal objectives. Legal objectives include pushing for more stringent regulations or enforcing international, supranational, and national climate law (Colombo, 2017), establishing state responsibility (Verheyen, 2005; Cox, 2014), or firm liability (Heede, 2014; Gage and Byers, 2014). In turn, political objectives and more generally societal objectives involve exerting pressure on policy-makers (Esrin and Kennedy, 2014), blocking the construction of fossil fuel infrastructure (Setzer and Byrnes, 2020), increasing media attention for the climate cause, and producing narratives of responsibility and urgency (Nosek, 2017; Hilson, 2019; Paiement, 2020), or giving voice to marginalized concerns (Lin, 2012). Lawsuits have thus come to constitute an element within the broader “contentious repertoire” (Tarrow, 1993; Tilly, 1993) of a growing social movement for climate justice (Esrin and Kennedy, 2014; Schlosberg and Collins, 2014; Boom et al., 2017; see Section 8.4).

Climate litigation is embedded in judicial, political, and constitutional institutions, which build the normative and political institutional framework at different scales (micro, meso, and macro) of the global order, as well as on different “local sites” (Hofius, 2016: 15; Wiener, 2018a: 51-52). They are specified by criteria such as access to justice (criteria for standing to sue, that is, the right to file a case in the first place); fundamental legal norms (including constitutional provisions or common law traditions, and the status of international law); dominant judicial practice (including the role of the judge and traditions in interpreting the constitution); scientific evidence to prove the facts relevant to the case (especially the causation between action or lack of action and damage or violation of a specific right or duty); and broader societal norms as a support for or a constraint against issues of climate justice.

Moreover, driver dynamics are influenced by a set of more specific enabling and constraining conditions. These include firstly the body of substantive and procedural law, which constitutes the basic conditions for bringing and arguing a case within a given jurisdiction. The thinner the legal basis in substantive law, the riskier and arguably more political the case becomes (Graser, 2019; Wegener, 2019). In addition to core regulatory bodies of climate change and en-

ergy law, legal requirements for the burden of proof (which party has to prove which parts of the facts) are of specific relevance. Furthermore, court rulings of higher-ranking judiciaries, or prior rulings as well as elements of judicial practice significantly shape climate litigation. Second, the status quo of scientific knowledge can act as an enabling condition, since it is closely linked to the legal conditions concerned with the proof of causality. Of particular relevance is the field of *attribution science*, which is concerned with establishing causation chains between anthropogenic greenhouse gas emissions, global warming, and specific extreme weather events (Burger et al., 2020), and the field of *climate economics*, which entails the calculation of costs and damages for future climate scenarios and transformation pathways (Tol and Verheyen, 2004). Third, societal factors influence the scope and content of climate litigation (Finnemore and Toope, 2001), including media coverage and framing, and the strength of social movements that campaign for climate justice. The latter may provide support via network capacities and encouraging potential plaintiffs. Furthermore, national and transnational litigation networks comprise agents operating at multiple sites and are thus able to make use of structures that comprise different scales of global order (Berman, 2009; Tully, 2016). These networks have the capacity to enhance the exchange of know-how and practice on the side of plaintiffs, defendants, and the judiciary, and together with environmental NGOs, to provide the financial and personal capacity necessary to bring climate lawsuits, to share their experience, and to ensure the quality of legal advice (Cummings and Rhode, 2009).

The climate litigation driver interacts with other social drivers of decarbonization, including climate-related regulation, UN climate governance, transnational initiatives, knowledge production, corporate responses, fossil fuel divestment, climate protests and social movements, as well as journalism.

Observations

Several dynamics can be observed in the climate litigation driver, and in its enabling and constraining conditions. Datasets of the Sabin Centre for Climate Law and the Grantham Institute/LSE Setzer and Byrnes (2020: 7-8) show a more or less steady rise in climate litigation from the year 2000 onwards. However, the absolute number of cases is much higher in the United States than elsewhere, and cases outside the United States are regionally dominated by cases in Australia, the United Kingdom, and the European Union (Setzer and Byrnes, 2020). Climate litigation in developing countries is growing, and often takes the form of “incidental” or peripheral cases. However, the use of incidental cases might in part be a strategic choice rather than a lack of intention to protect the climate (Setzer and Byrnes, 2020). Across several regions, there seems to be a *human rights turn*: a trend to invoke human rights as a basis for climate litigation (see also Esrin and Kennedy, 2014).

Examining the parties of climate litigation studies reveals that in the United States, the majority of climate change cases from around 2004 to 2014/2015 were increasingly brought by NGOs, and NGOs still represented the largest share of plaintiffs in 2016 (note that the studies summarized in this paragraph apply the broad definition of climate litigation as defined above for LSE/GRI and Sabine Centre databases; McCormick et al., 2018; Setzer and Byrnes, 2019). The next most frequent plaintiffs in the United States are, in order of frequency: industry groups, individuals or citizen advocacy groups, and businesses and corporations. Outside the United States, most cases were brought by corporations, followed by individuals and NGOs, but there are now obvious trends over time on the plaintiff side (Setzer and Byrnes, 2020: 8-9). On the defendants' side, almost 75% of climate cases were brought against governments, usually by corporations or individuals (Setzer and Byrnes, 2020). Setzer and Byrnes (2020: 11-12) also analyze outcomes of climate litigation and differentiate between outcomes that advance (favorable), undermine (unfavorable), or are neutral to climate action. For the time period between April 1994 until May 2020 they identify 187 (58%) favorable, 106 (33%) unfavorable and 28 (6%) neutral outcomes in cases outside the United States. Within the United States, a review of 534 cases in the period of 1990 until 2016 found that 42% had favorable outcomes (Eskander et al., 2020).

With a view to the institutional structures outlined above, only a few observations can be made at this early stage. Over the last decades, a growing number of constitutions adopted a right to a healthy environment, other constitutional safeguards of environmental protection, and broader standing rules to enhance access to justice in environmental matters, such as in the regional scope of the 1998 Aarhus Convention. There is furthermore a growing body of scientific evidence in attribution science (Marjanac and Patton, 2018; Burger et al., 2020), and the growing climate justice movement indicates a change in societal norms toward higher climate awareness. On the other hand, the growing polarization of the US Supreme Court and the cementing of a conservative majority with the nomination of three new Justices under the Trump administration will make it more difficult in the foreseeable future for successful climate litigation (or indeed to pass climate legislation) in the all-important US context (Brady, 2020).

Several dynamics can be observed in the legal enabling and constraining conditions. First, there is a growing body of climate-related legislation (Eskander et al., 2020; GRI and LSE, 2020; Setzer and Byrnes, 2020). Although the sheer number of climate laws in a country does not correlate with the number of climate-related lawsuits (Setzer and Byrnes, 2020: 9), a growing body of law enlarges and improves the substantive basis on which to bring and argue a case. If new or revised legislation goes along with more ambitious targets, it also enables climate litigation to raise the bar in this sense.

Another observable dynamic is that there is at least some progress in the legal arguing of causation. For example, in *Lluyja vs. RWE*, the Higher Regional Court in Hamm, Germany opened the stage of evidence, which presupposes that the court accepted the plaintiff's arguments in law (for an overview and documents of the case see Germanwatch, n.d.). This interim success has already set a new precedent for future cases. There are currently about 40 ongoing cases against the so-called *Carbon Majors*—the world's most carbon-intensive corporations—which will potentially profit from the advancements in attribution science (Setzer and Byrnes, 2020: 19). Also, the ruling in *Urgenda vs. State of the Netherlands* (for the case file see Urgenda, n.d.) is a recent landmark decision and includes several aspects that may serve as a "precedent" (not in the strict legal sense) in other jurisdictions, especially due to that the main foundation of the case lies in a human rights argument that is applicable in all regions with a human rights convention (Yoshida and Setzer, 2020).

Concerning the broader societal conditions, a growing body of literature on climate litigation (Setzer and Vanhala, 2019) and case law indicates an increase in legal know-how and practice. Furthermore, strategic climate litigation networks such as the Climate Litigation Network founded by Urgenda and older networks such as the Climate Justice Programme play an increasingly important role in supporting potential plaintiffs and circulating arguments and best practices, both in the Global North and in the Global South (Ciplet, 2014; Peel and Lin, 2019; Aykut, 2020). Finally, increased media coverage and uptake of litigation as a topic in social movements signal a broader supportive societal dynamic (Paielement, 2020).

The COVID-19 pandemic certainly influences climate litigation but it is not yet clear how and to what extent. On the one hand, climate litigation might slow down due to the shift in attention to health and economic concerns. On the other hand, rolling back climate regulation due to the pandemic could also trigger new climate litigation to prevent further erosion of regulation, somewhat similarly to what could be observed in the United States under the Trump administration (Setzer and Byrnes, 2019: 6; Setzer and Byrnes, 2020: 13). The pandemic also inhibits larger climate protests and thus an important element of societal support and embeddedness.

Looking forward

It is difficult if not impossible to directly attribute specific greenhouse gas emissions reductions to climate litigation. This observation notwithstanding, a range of possible positive effects of climate litigation can be identified (Nachmany et al., 2017; UNEP, 2017; Setzer and Vanhala, 2019; Setzer and Byrnes, 2020). First of all, there are case-specific effects directly attributed to the implementation of a specific ruling or settlement (Eilstrup-Sangiovanni and Bondaroff, 2014). The effects are as heterogeneous

as the claims themselves and may range from direct or indirect regulatory impacts such as the prevention of carbon-intensive infrastructure to change of behavior of companies. Within the legal sphere, a positive ruling on a case or even just a line of argument or a narrative in a claim may serve as a “precedent” case or inspiration for “insofar-comparable” cases in the same or even other jurisdictions (Osofsky, 2007). Moreover, a decided climate case shows opportunities and challenges in current substantive and procedural law, and may initiate strengthening of substantive and procedural provisions in the respective jurisdictions. On a structural level, climate litigation may trigger new alliances and enhance strategic litigation networks (Osofsky, 2005; Cummings and Rhode, 2009; Wiener, 2018a; Paiement, 2020). In this transnational societal context, norms of global climate governance evolve and change through the practice of climate litigation, which co-evolves with the active use of such networks.

Beyond immediate legal effects, climate litigation might therefore be even more relevant with a view to the broader societal dynamics toward deep decarbonization. A positive ruling may, for instance, serve as a signal for other actors (including legislators, administrations, and companies) and broader society to align their practices with the objectives of the Paris Agreement, such as via more ambitious legislation, more active administrative enforcement, fossil fuel divestment, or “greening” of business models (Franta, 2017). Climate litigation also contributes to knowledge production, such as in the field of climate science or economics (Marjanac and Patton, 2018). In providing media coverage to the climate cause, it also permits regular agenda-setting and intervenes in the co-production of wider societal narratives of responsibility and temporality in support of urgent climate action (Nosek, 2017; Paiement, 2020).

On the other hand, climate litigation may have a range of negative effects. For example, lost cases may become negative precedents and protect carbon-intensive activities. Holding governments accountable for their climate targets may prevent ambitious target setting. Cases against companies could also entail stronger lobbying against substantive climate protection law and against procedural rights to enforce substantive law in administrations, compliance control bodies, and courts. Climate litigation could also trigger opposition and contribute to a societal backlash. This is arguably currently visible in the US context, where the inability to pass bi-partisan climate legislation has led to an increase in climate litigation cases, after a landmark ruling by the US Supreme Court conferring the Environmental Protection Agency (EPA) the right—and the duty—to regulate CO₂ as a pollutant (US Supreme Court, 2007). The focus on the judiciary led to an increasing politicization of the courts, including Supreme Court nominations, and might well have contributed to a situation in which a stable conservative Supreme Court majority blocks ambitious climate legislation initiatives by the current US administration.

What becomes clear from this first collection of possible effects is that assessing impacts of climate litigation is a highly complex endeavor (Bouwer, 2020; Setzer and Byrnes, 2020). Looking at the observed dynamics of the driver, and its enabling and constraining conditions, we nonetheless venture a first cautious conjecture. We assume that individual and strategic climate lawsuits intended in favor of decarbonization and climate justice will further increase and spread geographically, driven by a growing body of climate legislation in many countries, the transnational circulation of legal know-how, growing scientific evidence for climate impacts and their attribution, and a growing transnational social movement for climate justice. However, climate litigation represents an increasingly important, yet on its own insufficient, driver for deep decarbonization. As the review shows, the effects of climate litigation have to be assessed in close connection with broader political, economic, and societal dynamics, which successful litigation can reinforce or counteract. Future research will therefore aim to add to the nascent research on the effects of climate litigation (Setzer and Vanhala, 2019) and further elaborate on a concept that traces dynamics of climate litigation, especially in interaction with related key drivers of decarbonization.

Resources generated by this driver

Climate litigation constitutes a social process where societal agents pursue political, legal, and overall societal objectives. And, especially where transnational litigation networks have been established and operate successfully in support of climate litigation across national boundaries, the particular transnational nature of this process reveals the global quality that is inherent to all objectives and purposes of climate litigation. Whether or not this global quality obtains an influential role in future climate policy-making is therefore an issue that requires more systematic research on the emergence of a novel *global opportunity structure* that is shaped and used by a multiplicity of global societal agents around the world. The leading question here is whether or not a driver generates resources of a global quality that become both visible and accessible to other societal agents?

Three resources stand out with regard to their dynamically evolving global quality: precedence (generated by legal cases); network capacities, constituted by transnational litigation networks spanning micro, meso, and macro scales and facilitating hybrid knowledge production; and agenda-setting, as spectacular litigation cases facilitate social media and traditional media coverage of climate issues. While this driver’s vital part in the dynamic generation of global resources is relatively undisputed, the degree to which these resources can be exploited to enhance the plausibility of deep decarbonization depends on the closely interrelated future dynamics of other drivers such as climate protests and social movements (Section 8.4), journalism (Section 8.9), and knowledge production (Section 8.10).

8.6

Corporate responses

In recent years, an increase of company commitments to reduce greenhouse gas emissions can be observed via communicated strategies available in sustainability reports as well as commitments to target setting initiatives (e.g., Science Based Targets, 2020). In addition, increasing academic publications have observed various corporate responses to climate change (e.g., Daddi et al., 2018; Seles et al., 2018). While these studies capture strategic positions and associated activities (Jeswani et al., 2008), greenhouse gas emissions stemming from business organizations are still increasing worldwide, exposing a “big disconnect” between corporate responses and macro-level developments (Dyllick and Muff, 2016). Additionally, it is important to note that the vast majority of companies still do not engage in any climate efforts.

Thus, if the driver continues its current trajectory, empirical evidence suggests that corporate responses will not necessarily support the social dynamics toward deep decarbonization. While some corporate practices are promising, further acceleration is needed in the coming years.

Driver description

Previous literature classifies corporate responses to climate change in two common frameworks: continuum models and typologies capturing a range of corporate strategies and associated activities. Jeswani et al. (2008) offer four general categories of corporate responses, including indifferent (companies that appear apathetic to environmental issues including climate change), beginner (companies with few, albeit unstructured operational activities), emerging (companies with structured operational activities, including management systems), and active (companies with innovative approaches with well-established carbon management systems). If business organizations are to contribute to deep decarbonization, the majority of corporate responses should resemble those of emerging and active companies in a relatively short amount of time. In reality, most companies are either indifferent or beginners of effective corporate responses (Dyllick and Muff, 2016).

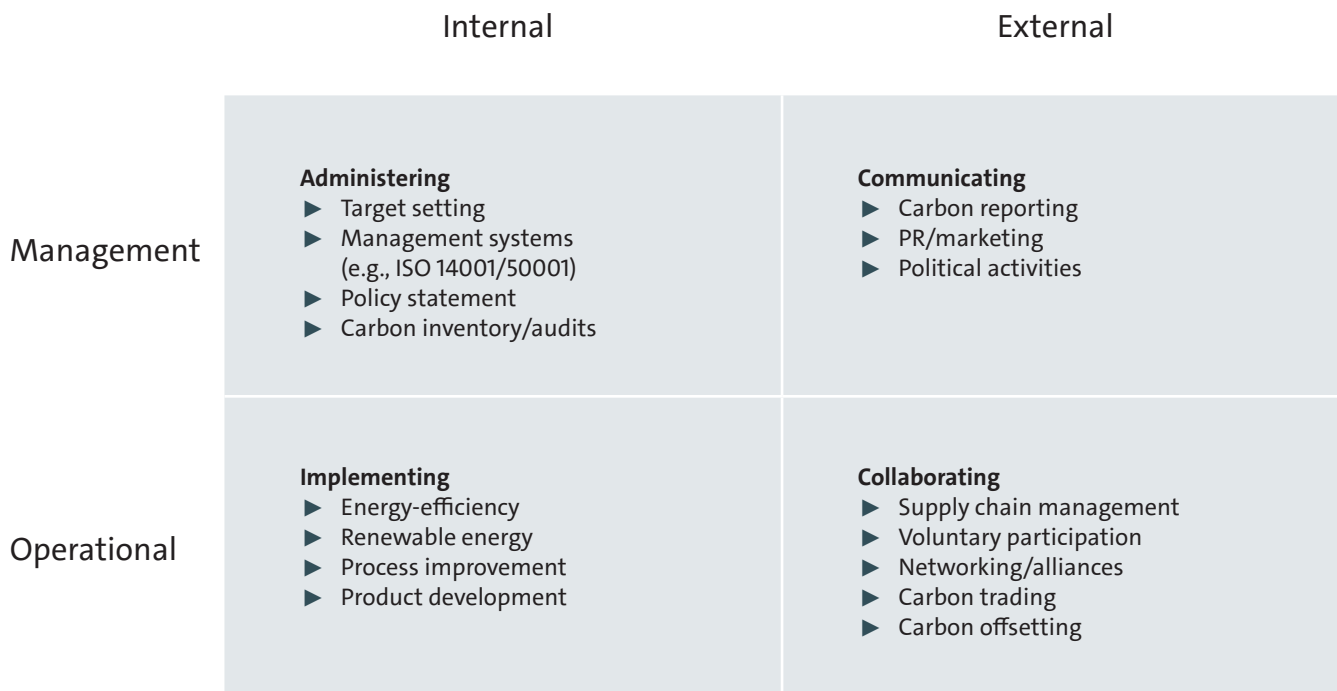


Figure 7: Schematic of corporate activities to mitigate greenhouse gas emissions

An additional component to corporate responses is the observable activities that business organizations employ, including operational and management activities. These activities can be further distinguished by their internal or external focus (Kolk and Pinkse, 2005). Figure 7 provides an illustration of business activities in two dimensions—type (management or operational) and focus (internal or external).

Activities resembling corporate responses can be grouped into four categories: administering, implementing, communicating, and collaborating. Since Dyllick and Muff (2016) call for a distinction between effective and ineffective corporate responses leading to absolute reductions of greenhouse gas emissions, these categories shall be further scrutinized according to the potential for absolute greenhouse gas emissions reduction (Slawinski et al., 2017).

From previous literature, activities proven most effective to reduce absolute greenhouse gas emissions include those found in the areas of *implementing* (i.e., energy efficiency, renewable energy, process improvement and product innovation) as well as *collaborating* (e.g., efforts in the supply chain). It appears that process improvement serves as an interface for several reduction activities. For example, process improvement can potentially combine the implementation of energy-efficient technologies in production as well as the increase use of renewable energy sources. Furthermore, process improvement is not a one-size-fits-all approach. For example, process improvements in high-emitting industries (e.g., chemicals, metals, transport, and oil & gas) frequently include the investment in new and innovative product technologies (Kolk and Pinkse, 2004), while in low-emitting industries (e.g., insurance, finance, and telecommunications) the implementation of energy conservation programs would suffice (Kolk and Pinkse, 2004; Galbreath, 2010).

However, operational activities rarely appear to succeed on their own. They require the combination of sound management activities to achieve effective corporate responses, including target setting (e.g., reduction of greenhouse gas emissions by 50% within 10 years), carbon measurement and reporting, and the adoption of energy and carbon management systems (e.g., ISO 50001). While the other areas, including communicating and collaborating, can provide the impetus for significant reductions in greenhouse gas emissions, several activities in these categories have been criticized for delivering symbolic gestures rather than substantial improvements, which detracts from efforts toward deep decarbonization within regions and industries (Boiral et al., 2012; Elijido-Ten and Clarkson, 2017). For example, Elijido-Ten and Clarkson (2017: 1068) state that managers adopt reporting “opportunistically in an attempt to change stakeholder perceptions by making unsubstantiated claims about their actual performance, as well as their plans and strategies going forward.” Rather, companies must consider a coordinated set of internal and external activities that are able to fulfill a progressive and substan-

tial response to absolute reduction in greenhouse gas emissions (Jeswani et al., 2008; Weinhofer and Hoffmann, 2010; Damert et al., 2017).

Enabling and constraining conditions

Established international climate policies, national targets, carbon markets, and reporting standardization can be enabling conditions for effective corporate responses to decarbonization. Examples of trends heading toward decarbonization in many industries, especially with energy providers, have been witnessed with Germany’s Energy Transition (*Energiewende*). For example, German government provided the necessary regulatory and financial impetus through the so-called *feed-in tariffs* to encourage firms to install on-site renewable technologies, such as wind and photovoltaic power systems (Schmid et al., 2016). Furthermore, carbon markets such as the EU Emissions Trading System (EU ETS) have targeted on energy-intensive sectors to be assigned various targets in order to cap and reduce greenhouse gas emissions accordingly.

However, an institutional structure that discourages active corporate responses to decarbonization is embedded in market-dominant logics (Thornton et al., 2012). While market logics are dynamic and can combine with other logics such as ecological logics (York et al., 2016), the existing market logic, which prioritizes above all economic growth, encourages companies to remain indifferent and inactive with respect to decarbonization goals (Slawinski et al., 2017). Furthermore, market logics are deeply embedded into organizational procedures and managers’ cognition, further exacerbating any efforts to overcome short-term, growth-oriented decision-making (Slawinski et al., 2017; Wright and Nyberg, 2017).

Several more dynamic enabling conditions include national targets, carbon markets and industrial standardization, financial support, and NGO programs. For example, the Science Based Target Initiative (SBTi), in which over 1000 major global corporations have recently committed and communicated targets, aims to reduce greenhouse gas emissions in line with a scenario well below 2°C of global warming. Many of these enabling conditions are considered non-market drivers—including voluntary programs, NGO support, and media/public awareness—that might not push the majority of companies to join due to the lack of economic incentives.

Furthermore, a number of the other social drivers—including climate-related regulation, private investments and divestment, UN climate governance, actual or anticipated climate litigation, knowledge production, consumption patterns, and climate protests and social movements—influence corporate responses to varying degrees. Climate-related regulation (Section 8.3) is one of the most impactful drivers, as it can influence corporate responses via policy instruments, such as carbon markets and mandatory reporting schemes, in-

cluding the EU Emissions Trading System and EPA's Greenhouse Gas Reporting Program (Busch et al., 2020). While these regulations often have a strong regional and/or national focus, they can promote greater transparency, and actually regulate and reduce facility-level emissions when combined with market-based policies, such as cap-and-trade (Engels, 2009). Beyond this regional focus, corporate responses are influenced by UN climate governance (Section 8.1) and transnational initiatives (Section 8.2), which can provide a source of new international norms, including CDP and the SBTi (2020).

Corporate responses are also strongly influenced by financial markets. Beyond policies, both investments and divestments provide an impetus to change toward deep decarbonization (see Section 8.7). This can level the playing field, encouraging radical innovation while introducing economic penalties for the pervasive business-as-usual paradigm. Additionally, corporate responses are influenced by knowledge production (Section 8.10) to some extent, since universities and research centers can act as intermediaries to assist in proactive responses and implementation of concrete actions (Yusuf, 2008). Consumption patterns could potentially encourage companies to behave in climate-friendly ways. However, consumption patterns currently inhibit deep decarbonization (see Section 8.8), and thus, cannot act as catalysts to move companies toward deep decarbonization at this point in time. Finally, climate protests and social movements (Section 8.4) attempt to encourage shifts of market logics to environmentally friendly solutions, such as the push to adopt wind energy in the United States (York et al., 2016).

Alternatively, corporate responses interact with several drivers to encourage further change in a more rapid fashion. Corporate responses can influence knowledge production and consumption patterns, especially when process improvements and product developments lead to low-carbon innovations. Additionally, corporate responses can encourage further climate-related regulations and investments, especially when policy-makers observe positive, active reactions to existing climate-friendly policies.

Driver dynamics

Increasingly more companies are reporting and setting targets for their greenhouse gas emissions as part of an externally oriented response to institutional pressures (Busch et al., 2020). CDP (2019) reveals the trend of companies disclosing climate change information, which have increased in number from 228 companies (2003) to 8361 companies (2019). Furthermore, more companies are setting climate targets and participating in climate-related networks on both local and national levels (Dahlmann et al., 2017). For example, the SBTi has revealed that more than 1,000 companies are taking action according to science-based targets (Science Based Targets, 2020). Though company

commitments and further initiatives, like the UN program Caring for Climate under the UN Global Compact (2020) point toward deep decarbonization, it is truly difficult to assess if we are near a critical mass of change.

Even though these trends appear to be promising, little is known about whether corporate communications and target setting translate into practical action. A recent study provides some insight into the effectiveness of substantive and symbolic target setting and finds that substantive targets with absolute targets spanning longer periods of time to have a greater effect on greenhouse gas emissions reduction (Dahlmann et al., 2017). A further study finds that corporate carbon data is inconsistently reported to various media channels, including company reports and voluntary reporting schemes, such as CDP (Busch et al., 2020). Thus, further research is required to assess effective and ineffective actions for business-related decarbonization.

Additional aspects of corporate carbon data must be properly accounted for, especially the monitoring and measuring of greenhouse gas emissions in global supply chains (i.e., Scope 3 emissions), which is currently lacking. Mandatory reporting schemes, including the EU Emissions Trading System and the US Environmental Protection Agency's Greenhouse Gas Reporting Program, mostly cover companies' direct (Scope 1) emissions. In order to foster a clearer assessment of corporate responses to decarbonization, recent studies urge for universal standards of greenhouse gas accounting and reporting (Busch et al., 2020). The improvement of corporate carbon data, especially in supply chains (external), would provide clearer indications of how corporate responses could offer pathways toward decarbonization.

Furthermore, the market for carbon offsets has increased. Kolk et al. (2008) explain that small firms and non-profit organizations such as Atmosfair in Germany and TerraPass in the United States sell offsets to consumers and firms who wish to offset their greenhouse gas emissions. Another option for offset projects is the Clean Development Mechanism by the United Nations Framework Convention on Climate Change (Weinhofer and Hoffmann, 2010; Sprengel and Busch, 2011). Finally, carbon offsetting can be centralized, creating carbon markets that sell offsets within a cap-and-trade mechanism, such as the EU Emissions Trading System, where current trends show an increasing price for allowances together with a slight but steady reduction in greenhouse gas emissions. While some of these programs can support and/or coerce industry-wide corporate responses in the direction of decarbonization, many authorities remain critical about the effectiveness of carbon offsetting. Kolk et al. (2008) mention that offsetting may cause unintended consequences, even an increase in net emissions. Weinhofer and Hoffmann (2010) find that by offsetting emissions, companies can decrease external pressure to reduce their emissions, and therefore do not solve the underlying problem.

Currently, the COVID-19 pandemic has offered a temporary reduction of global greenhouse gas emissions. However, sensitivity tests already find that emissions will drastically increase post-pandemic in most global economies (Le Quéré et al., 2020). Economic recovery packages intended to boost trade and spending may reduce the strength of previous policies that coerce companies into reducing absolute greenhouse gas emissions. If this occurs, it may create further regulatory uncertainty that stalls companies' efforts toward deep decarbonization, and may constrain future political and institutional efforts to promote deep decarbonization.

Looking forward

Although there is an observable increase in corporate responses to climate change, it remains uncertain to what extent these responses can achieve deep decarbonization without necessary governmental regulations, institutional pressures, and the support of financial markets. Slawinski et al. (2017: 254) emphasize that the majority of corporate responses are summed up as organizational inaction, defined as “the failure to reduce absolute greenhouse gas emissions due to the lack of effective measures.” As long as the market-dominant logic advocates economic growth at any cost, including the natural environment, it is highly plausible that corporate responses will not support the required social dynamics toward deep decarbonization.

While combinative activities, including management (e.g., target setting) and operational activities (e.g., process improvement) hint at the ability for business organizations to reduce absolute greenhouse gas emissions, these practices are currently not observed in most companies. It appears that outside forces also work against these efforts, including regulatory uncertainty and lack of market and institutional incentives. As long as government policies and financial markets tolerate carbon-intensive practices, most corporate responses toward decarbonization will be superficial at best. As Wright and Nyberg (2017: 1657) emphasize: “business leadership on climate change alone is insufficient to provide the dramatic decarbonization needed to avoid dangerous climate change.”

Even the exemplary efforts of a few companies appear to deteriorate over time, as the market-dominant logic places extreme tensions on firms to conform to economic growth and short-term profit maximization (Wright and Nyberg, 2017). Thus, this driver will continue its projected course unless carbon mitigation efforts prove to become more profitable, for example, through technological progress and innovations. Foremost, stringent climate policies—notably a significant carbon tax—could stimulate a change in the direction of the driver.

A further indicator for changes in the driver would be if target-setting initiatives, such as Science Based Targets (2020), create substantial reductions of absolute greenhouse gas emissions, especially in high-emitting sectors—but this does not appear to be the case. Empirical evidence shows that high-emitting companies, including metals, transport, and oil and gas hesitate to commit to such targets, and the companies that do commit do not automatically lead to deep decarbonization (Dahlmann et al., 2017). Instead, many signs point to higher emissions, especially in supply chains that are often not captured by target setting. However, this could change in 2021, since international policies may focus on improved carbon measures and additional mechanisms, such as tariffs on imported goods to counteract carbon leakage (e.g., the EU Carbon Border Adjustment Mechanism).

The majority of the contemporary literature indicates that some existing corporate responses could potentially lead to substantial efforts toward deep decarbonization, but that these efforts are still rare. This emphasizes that corporate responses are currently not establishing the necessary conditions for deep decarbonization on their own, nor are they likely to do so in the next decade, which indicates that this driver will not plausibly support the social dynamics required for deep decarbonization by 2050, unless disruptive carbon-reducing technologies coupled with financial incentives and strict climate-related regulations change the driver's current trajectory.

Resources generated by this driver

Corporate responses might be able to provide global resources accessible to other social drivers and actors. When companies develop cost-effective technologies and bring these to market, this can have a positive effect on supportive climate-related regulations, such as the Clean Development Mechanism (Jeswani et al., 2008), and attract further investors (Kolk et al., 2008). Corporate responses may also encourage positive shifts in consumption patterns, such as promoting lower carbon emissions in the product use phase, especially when effective messages are communicated to the end-consumer (Morgan et al., 2018).

8.7

Fossil fuel divestment

Driver description

The extraction of fossil fuels requires massive financial investments over long amortization periods. *Fossil fuel divestment* is an important dynamic that can initiate, accelerate, and intensify the replacement of fossil fuels. It is plausible to assume that discontinued financial flows to fossil fuel industries will lower global emissions levels discernably. Due to the long investment cycles (Kenny et al., 2010), infrastructural inertia (Waisman et al., 2012; Bertram et al., 2015) and long-term power purchase agreements in fossil fuel industries (Trencher et al., 2020), the next decade will be decisive for determining whether deep decarbonization will be achieved by 2050.

Definition

Fossil fuel divestment is the process through which financial flows are withdrawn from fossil fuel industries or fossil-fuel-intensive industries and thus falls into the category of supply-side policies and activities (Gaulin and Le Billon, 2020). Fossil fuel divestment comprises any reduction or cessation of investment or financial support for upstream (extraction) or downstream (e.g., energy provision) fossil fuel activities and divestiture or a more general shift in business priorities from fossil fuels to non-fossil fuels (in analogy to coal divestment in Rosenbloom and Rinscheid, 2020; Trencher et al., 2020). This is thus a more encompassing concept of divestment than just referring to divestment campaigns by non-state actors (Gunningham, 2017b). Divestment can also be a direct effect of state policies or divestiture decisions in private or state-owned enterprises (Mayer and Rajavuori, 2017) or private or public pension funds. This does not predefine into which alternative industries and fields of economic production financial flows are re-invested, or the emissions impact of these redirected financial flows. The flows are formed at global, national, and sub-national levels, and it is therefore currently impossible to generate a complete overview of global financial flows. The driver assessment is therefore based on a conceptual approximation, selective data sources, and a literature review.

Conceptual approximation

The decision to discontinue fossil fuel business can be driven by market forces, public pressure, normative pressure by stakeholders, state policies, or legal reform. Market forces would apply if the expected profitability of fossil fuel activities declines. Investors would then disinvest directly, or would choose to use their stakeholder influence to steer companies away from fossil fuel activities (normative pressure). Pub-

lic pressure via protest movements can be another direct influence on investors' decisions, but to a limited extent, as they can only affect parts of the financial flows, mainly those that go to companies that are publicly listed. However, public and normative pressures can also have indirect influences on the profitability of fossil fuel activities over longer time periods. States are important actors as they can change the regulatory framework, and are often themselves heavily invested in fossil fuel activities (through state-owned companies, state funds, and tax income). Legal reform can improve transparency (through sustainability-reporting standards) and also more directly discourage fossil fuel investments. Investments and divestments on financial markets take place in split seconds. However, directing financial flows away from fossil fuel engagements in the long term requires the widespread development and stabilization of the expectation that these investments will become stranded assets in the next one or two decades.

Sources

Several activist organizations, academic initiatives, and UN bodies collect data on divestment activities (e.g., SEI et al., 2019; Gaulin and Le Billon, 2020; GoFossilFree, 2021; 350.org, n.d.; BankTrack; UNFCCC). An extensive literature review was undertaken.

Observations

The plausibility of reaching a tipping point (Otto et al., 2020) toward fossil fuel divestment increases if large (private or public) investors and companies become increasingly convinced that the financial risk of fossil fuel investments is too high. This conviction may come from political pressure, moral stigmatization, regulatory changes, and directly from market forces. Based on the conceptual approximation, we ask the following questions for our assessment: What divestment pressures and activities can we currently observe? How far are divestment pressures and divestment declarations actually leading to the termination of fossil fuel activities? Are domestic divestment activities consistent with international activities, or do we see a relocation of investments in fossil fuels? How do costs of divestment evolve compared to continued profits by fossil fuel investments? To what extent are key actors building up expectations about the risk of stranded assets?

What divestment pressures and activities can we currently observe?

An increasing number of institutional investors have already taken divestment decisions, including higher education institutions, pension funds, insurance companies, asset management companies and hedge funds, faith-based organizations, and medical and health institutions (Ayling and Gunningham, 2017). This trend started as a political movement in universities with large endowed capital, and investors with high visibility later joined (e.g., the Norwegian state fund and the global insurance company Allianz in 2015). BlackRock, the world's largest asset manager, published a coal divestment pledge in January 2020. The NGO 350.org, which specializes in collecting divestment information, estimates the total value of institutions divesting to date (09 April 2021) at \$14.56 trillion (GoFossilFree, 2021). Moreover, companies also report direct divestitures of fossil fuel assets. However, private and public investments in fossil fuel exploitation still continue. New coal fired power plants are built, new coal mines and oil and gas fields are developed. Many investors who publicly declared a divestment strategy continue to be heavily invested in fossil fuel activities. For example, BlackRock was reported to still hold \$85 billion in coal one year after their divestment announcement (Jolly, 2021). This is complemented by national fossil fuel investment plans that still diverge from the scenario of deep decarbonization by 2050 (Piggot et al., 2020). The annual *Production Gap Report* stated in 2019 that governments are planning to invest in the extraction and use of about 50% more fossil fuels by 2030 than would be consistent with a 2°C pathway and 120% more than would be consistent with a 1.5°C pathway (SEI et al., 2019). In the 2020 update of that report, the authors emphasize that the post-COVID-19 stimulus measures will decide on the direction of the future dynamic of investments (SEI et al., 2020). Current evidence suggests that the total global investment in fossil fuels still outweighs the declared divestment, which indicates that this driver is not yet sufficient to drive deep decarbonization.

What is the relation between divestment declarations, implemented divestments and termination of fossil fuel activities?

There is no complete and reliable overview of the effects of divestment declarations. However, multiple empirical examples indicate that the effects of fossil fuel divestments remain modest. A recent study of 15 OECD pension funds representing €79 billion in liquid fossil fuel assets shows that they generally prefer engagement over divestment, that they do not use engagement to push companies to terminate fossil fuel activities, and that no pension fund expressed industry-wide divestment (Rempel and Gupta, 2020). Another study on Dutch pension funds reveals that they underweight carbon-intensive industries rather than divest from the most carbon-intensive firms within industries (Boermans and Galema, 2019). Although pension funds often

experience pressure from stakeholders to divest or invest in climate-friendly assets, their governance structures might buffer them from succumbing to the pressure (Stewart, 2019). The analysis of finance arrangements in Japan shows a slowdown, but not a cessation of new and existing coal-related investments (Trencher et al., 2020). In a large study on institutions with more than \$100 billion in assets under management, divestment is the least frequently used tool among 12 possible approaches to manage climate risks (Krueger et al., 2020). Divested firms are often bought by less scrupulous investors, and fossil fuel activities are continued (Afero et al., 2017; Ayling and Gunningham, 2017). Obviously, even precisely targeted divestment campaigns do not necessarily prevent long-term investments in new extraction activities (Curran, 2020).

Are domestic and international divestment activities consistent, or do we see a relocation of investments in fossil fuels?

There are considerable mismatches between domestic divestment activities and foreign divestment behavior. The mismatches can be found at different levels and can point to different directions. Norway uses its domestic fossil fuel production to feed its state pension fund. The fund, in turn, promotes fossil fuel divestment as a global strategy (Hunnes, 2019). Coal-producing countries like Japan and China, on the other hand, might divest to some degree domestically, but reinforce at the same time their foreign fossil fuel investments (Edwards, 2019; Trencher et al., 2020). The mismatch also takes on another pattern which was revealed in a comprehensive study on fossil fuel cut activities in 106 countries between 1988 and 2017, which revealed that most fossil fuel initiatives occurred in countries with low domestic carbon entanglement (Gaulin and Le Billon, 2020). Furthermore, a recent study of equity and bond issuance and syndicated loan transactions in 33 countries from 2000 to 2015 revealed that domestic banks situated in countries with high divestment commitments and stringent environmental policies provide more finance to oil and gas companies abroad (Cojoianu et al., 2019).

How do costs of divestment evolve compared to continued profits by fossil fuel investments?

While higher education institutions engaged early in divesting their endowment portfolios (Beer, 2016), substantial transaction, monitoring, and active management costs arose from this divestment. These costs were estimated to be 2–12% over 20 years, representing a meaningful decline of their endowments (Bessembinder, 2016). It is difficult to say if this cost estimate would be transferable to other types of institutional investors, such as private asset managers, and to larger asset portfolios. Concerning the financial performance of large portfolios, there might be a diversification loss due to divestment. However, the financial performance of divested portfolios for large institutional investors

(e.g., hedge funds) has been shown to be at least comparable to high-carbon portfolios in recent, comprehensive studies (Trinks et al., 2018; Plantinga and Scholtens, 2020). Divestment announcements decrease the share price of fossil fuel companies, but so far have not been successful in inflicting significant economic damage on fossil fuel corporations (Dordi and Weber, 2019).

To what extent are key actors building up expectations about the risk of stranded assets?

Anticipated futures strongly influence strategic investment behavior (Engels et al., 2020). The anticipation of future policies can already lead to divestment activities ten years ahead of policy implementation (Bauer et al., 2018). The expectation-building and what influences this process can vary between types of investors, it can diffuse via herd behavior (Benz et al., 2020) and can be fostered through various channels (e.g., political pressure, cultural diffusion, litigation, legal framework, policies). The question is whether this will reach a critical mass so that this dynamic eventually leads to a tipping point on financial markets (Otto et al., 2020) and state investments. The evidence is mixed.

Political pressure: One study combined data on portfolio divestment activities in 23 countries from 2010–2018 with country-level values for climate awareness and found a strong correlation between the level of awareness and the level of carbon divestment after 2015 (Choi et al., 2020). Political pressure and the diffusion of climate change knowledge and pro-climate values can thus be an important motivator for further divestment activities.

Cultural diffusion: A discourse analysis of social movements and the financial sector shows that key concepts such as 2°C carbon budget, stranded assets, carbon bubble, divestment, and anti-pipeline campaigns have diffused from the fringe to the mainstream in under 10 years (Strauch et al., 2020). Studies on the effects of the divestment movement demonstrate that even though the direct divestment effects might be low, indirect effects like normative shifts, political pressure on governments and a revival of pro-environmental social movements can support supply-side policies over time (Ayling and Gunningham, 2017; Bergman, 2018).

Pressure by litigation: The legal framework for investments is currently debated. Fiduciary fund management obligations can be interpreted both as an obligation to divest from and as an obligation to continuously invest in fossil fuels. The first interpretation is based on the need to secure ethical integrity and prevent reputational damage, and the need to hedge or avoid stranded asset risks. The second interpretation is based on the expectation of a stable and competitive return on investment provided by fossil fuel engagements (Richardson, 2017; Scott, 2020). Because legal frameworks that

define the possibility for litigation vary substantially across jurisdictions, it is impossible to observe a general trend.

Regulatory changes: The current regulatory framework for investments typically does not directly constrain continued investment into fossil-fuel-based industries, or even allows further subsidization of fossil-fuel-based activities. In many countries, state revenues depend on profits coming from fossil fuel industries (carbon entanglement; Gurría, 2013). National and international laws regulating financial flows usually guarantee the freedom of investment (although with some conditionality and transparency requirements).

Anticipation of risk of stranded assets: A broad survey and interview study on investors in the UK and Australia reveals that in 2014/15, ignorance about climate-related risks and about their implications for the investment institution abounded (merely 30% had heard about stranded asset risks; Harnett, 2017). A more recent survey among institutional investors finds that 43% of the respondents have talked with managers of companies in their portfolio about climate risks, 50% state that climate risks related to regulation have already started to materialize, and only a minority (7%) has chosen no approach to manage their climate risks during the 5 years preceding the survey (Krueger et al., 2020). A 2018 survey of 30 UK-based asset managers representing organizations with total investments over £13 trillion also found mounting expectations of climate risks among key actors. Fifty-four percent of respondents answered that reputational damage was already having a negative impact on valuations in fossil fuel industries, while a further 25% expected an effect to emerge over the next two years. Almost all respondents agreed that regulatory risk would be an issue within the next five years (UKSIF, 2018 cited in Macpherson, 2019).

Looking forward

We conclude that so far, no hard, empirical evidence exists that divestments have taken place in volumes that will lead to a discernable change in direction of the fossil fuel industries within the next decade. We observe that the driver does not contribute yet in any direct way to the plausibility of achieving deep decarbonization by 2050. However, a critical juncture might be reached if expectations of future developments held by investors change more intensely in the next few years. This might lead to a situation in which large investors like pension funds face such strong divestment pressures that they reject fossil fuel investments, instead of using organizational buffers to maintain fossil fuel engagement in their core business activities. The economic recovery programs in a post-COVID-19 phase will crucially either contribute to the cementation of continued fossil fuel exploitation, or serve as a

bifurcation point. An overall assessment also has to take into account possible negative spillover effects (Neville, 2020) and huge implications for climate justice. As a strategy for political protests, active engagement might be a better instrument than plain divestment. A strong reason for why we assume that financial flows will continuously enable fossil fuel extraction is the role of state actors and carbon entanglement of states (Gurría, 2013).

If divestment increases, however, and reaches a globally visible critical mass, it would provide resources for a global opportunity structure, by marking the end of profitable fossil fuel engagements. Politics and regulation could be directed toward deep decarbonization with increasing legitimacy, and climate litigation could also draw on evidence concerning economic expectations.

8.8

Consumption patterns

Driver description

Consumption patterns are defined here as the expenditure patterns of income groups across or within categories of products and services, such as food, clothing, transport, energy, and discretionary items (Dholakia and Firat, 2011: 351; Sharma et al., 2018). Consumption patterns are thus amongst the key drivers of social transformations that may drive or hinder climate change mitigation.

Studies estimate that household consumption contributes to more than 60% of global greenhouse gas emissions and show that wealthier countries such as the United States and Australia generate the most significant impacts per capita (Ivanova et al., 2016). Furthermore, the UN latest projections reveal that the global population might grow to around 9.7 billion by 2050 (UN, 2020), and even more conservative projections indicate continued population growth until 2050 (e.g., Lutz, 2019; Vollset et al., 2020). Increasing global population until 2050 will lead to increasing global consumption and production, which will have important spillover effects on decarbonization and other climate-related goals (TWI - The World in 2050, 2020: 51-53). Hence, examining recent developments in consumption patterns provides valuable insights into the impact of this driver on the plausibility of deep decarbonization by 2050 and into possible rebound effects in the wake of the COVID-19 pandemic (see Box 4). For the purpose of this assessment, *rebound effects* refers to behavioral adjustments in response to a temporary improvement in terms of global emissions (after Colmenares et al., 2020).

Patterns of consumption in the energy and food sectors, which are influenced by socioeconomic and cultural factors and shaped by infrastructural conditions, have the greatest impact on global emissions. These two sectors are therefore at the core of this assessment. The breakdown of global greenhouse gas emissions by sector (measured in carbon diox-

ide equivalents) shows that energy makes up nearly three-quarters of total emissions (73.2%), followed by agriculture (18.4%), industry (5.2%), and waste (3.2%). Within the energy sector, electricity and heat generation represent the largest portion of emissions (29.7%), followed by transportation (15.6%), and manufacturing (12%). In turn, if the food system is considered as a whole (i.e., if processing, packaging, transport, and retail are integrated with agriculture and land use) its impact share makes up one-quarter of the world's greenhouse gas emissions (Poore and Nemecek, 2018; Ritchie, 2019; Ritchie and Roser, 2020).

The following assessment finds that global consumption patterns are characterized by extreme inequalities. Moreover, the outputs and transformations in the energy and food sectors depend on infrastructural conditions, regardless of the intention of individuals to change their consumption patterns. In this assessment, we first describe the institutional conditions for the development of mass consumption and the enabling and constraining conditions for specific consumption patterns. We then explore the recent developments in energy- and food-consumption patterns and consider the expected rebound effects in global emissions. Finally, we provide a conjecture about the plausibility of deep decarbonization by 2050 in light of the assessed evidence on global consumption patterns.

Institutional conditions for mass consumption

The vast majority of political systems worldwide do not limit the extent of individual consumption. To maintain legitimacy and stability, liberal democracies typically refrain from restraining consumption behavior and interfering with the freedom, choice and lifestyles of individuals, which results in a sus-

tained system of mass consumption (Blühdorn, 2019). Boström (2020) points to four core institutional conditions for the development of such a system, which are key for understanding the worldwide patterns of consumption. The first is capitalism, which is oriented toward continued growth or capital accumulation. The second comprises the steady industrial and technological development that has led to enormous increases in productivity over time, the creation of new “needs” and thereby to a boom in the consumption and production of products and services. The third institutional structure that facilitates the production, distribution, and consumption for the masses includes the economic geography that facilitates mass accessibility and availability of goods. This includes a constant process of urbanization and the internet as large-scale facilitators of standardized mass consumption patterns. Finally, the expansive character of capitalism, particularly represented by the predominance of a pro-economic growth principle, is another key institutional condition for mass consumption (Boström, 2020).

Enabling and constraining conditions for specific consumption patterns

Since the end of World War II, the world has witnessed an ever-increasing consumer interest and demand enabled by the exponential growth of post-war capitalist economies and the intense entanglement of identity and consumerism (Ritzer and Jurgenson, 2010; Blom, 2017). Social relations, everyday interaction rituals as well as social comparison also influence consumption patterns (Boström, 2020). For example, food consumption (e.g., meat) often goes beyond biophysical basic needs (e.g., nutritional needs) and involves a series of cultural practices and meanings as well (e.g., bringing close friends together for a traditional barbecue; cf. Grauel, 2014). In addition, socio-economic factors fundamentally affect the ability of people to consume goods and services and thereby enable or constrain reductions in carbon emissions. Higher income and life standards, for instance, are often associated with higher consumption and thus higher emissions (Steinberger et al., 2012; Büchs and Schnepf, 2013; Liang et al., 2016; Pang et al., 2019).

Change in individual consumption of goods and services is difficult to estimate because it is the outcome of complex social dynamics. Whereas the consumption patterns of individuals are either relatively stable or subject to incremental changes, they might vary considerably across different cultural, economic, political contexts (Welch and Southerton, 2019). Hence, it is difficult to take a snapshot of global consumption patterns and trends. The same is true for making interlinkages between this and other social drivers of decarbonization such as climate protests and social movements or corporate responses. Yet, knowledge pro-

duction and especially climate-related regulations are two social drivers that might influence the way in which consumption patterns evolve. Climate-related regulations can be particularly influential, because regulation sets standards for production and thereby directly influences the range and the type of available consumer goods.

Changing current carbon-intensive social practices is extremely difficult. Nonetheless, synergies between the production of climate change knowledge and the implementation of climate-friendly laws, regulations, and infrastructures are important enabling conditions for low-carbon consumption patterns (Engels, 2016; Wang et al., 2021). Some studies argue that climate policies that are targeted at household consumption and behavioral decisions support decarbonization (e.g., Dubois et al., 2019), but there is no consensus that this is the case. In turn, knowledge production concerning the obstacles to sustainable production and consumption systems (Vergragt et al., 2014) are crucial to support the design and implementation of climate-friendly laws, regulations, and infrastructures.

Recent trajectories of worldwide consumption patterns

Energy consumption

In the last sixty years, global greenhouse gas emissions caused by the energy sector have almost quadrupled. The same is true for carbon dioxide emissions, which increased from 8.02 GtCO₂ in 1957 to 32.1 GtCO₂ in 2017 (Climate Watch, n.d.). So far, energy consumption has been characterized by large inequalities within and across countries.

In 2017, over 60% of global emissions came from just six countries (China, the United States, India, Russia, Japan, and Germany), while the 100 lowest-emitting countries contributed less than 3% of global emissions (Climate Watch, n.d.). Energy sector data shows that the average person in wealthy countries like Iceland, Norway, Canada, the United States, Oman, Saudi Arabia, and Qatar consumes up to 100 times more than the average person in some of the poorest countries around the world (Ritchie, n.d.). Recent studies pointed to a strong correlation of income (GDP) and energy consumption and revealed that energy consumption inequality has been declining. This is due to the rising energy consumption in countries where income grew, and to improvements in energy efficiency in richer countries where energy consumption is actually falling (Bianco et al., 2019; Semieniuk and Weber, 2020; Ritchie, n.d.). In 2017, the International Energy Agency (IEA) reported that “the number of people without access to electricity fell to below 1.1 billion people for the first time in 2016”, but highlighted that progress in energy consumption inequality has been uneven and that due to population growth, there were more people without electricity in 2017 than there were in 2000 (IEA, 2017). More recently, the

agency estimated that 850 million people around the world still lacked access to electricity (IEA, 2019) and showed that lower income countries suffer the greatest and longest impacts on energy access and consumption due to the overarching consequences of the COVID-19 pandemic (IEA, 2020d).

IEA reports that by mid-April 2020, the energy demand in countries in full or partial lockdown declined by an average 25% and 18% per week respectively due to the COVID-19 pandemic (see also Box 4). In the first quarter of 2020 alone, global energy demand decreased by 3.8% (IEA, 2020d: 3-4) and global electricity demand decreased by 2.5%—the largest decline in more than 50 years (IEA, 2020b). The significant decline in electricity demand in 2020 favored the global generation of renewable energy, since priority access was given to the renewable electricity grid and the sustained installation of new renewable energy plants (IEA, 2020b). The global generation of renewables increased by 6.6% in 2020, representing the largest ever in absolute terms (IEA, 2020b: 24). Notwithstanding the unprecedented levels of energy demand decline and renewables grow, the annual decrease in global electricity consumption was smaller than the IEA forecasted in April 2020 (2% instead of 5%), due to the strong recovery in China and to a lesser extent in India (IEA, 2020b: 11; see also Wang et al., 2020). According to the IEA, “electricity demand rebounded sharply after initial shock, and is back to pre-COVID-19 trends in 2020 third quarter” (IEA, 2020b: 15-16). Hence, if the vast investments in economic recovery do not focus on cleaner and more resilient energy infrastructure, the rebound in energy consumption and greenhouse gas emissions tends to continue (IEA, 2020d: 4).

Transportation (a subsector of energy) is amongst the fastest-growing sources of global emissions; since 1990, transport emissions grew by 71% (Ge and Friedrich, 2020). Transportation is also a field of sharp inequality. A recent study finds that flying internationally is the privilege of only 2 to 4% of global population, and that merely 1% are responsible for 50% of CO₂ emissions from commercial aviation (Gössling and Humpe, 2020). In the aftermath of the COVID-19 outbreak, the global average road transport activity fell almost by 50% of the 2019 level by the end of March 2020 due to global lockdown measures, while air travel has almost come to a halt in certain regions (IEA, 2020d: 18). However, studies reveal that whereas the transportation sector can be highly responsive to policy changes and economic shifts, no structural changes in the economic, transport, or energy systems can be observed (Beltermann et al., 2020; IEA, 2020d; Le Quéré et al., 2020). Furthermore, “behaviors in response to COVID-19 could spark a rebound in transport-related oil use when countries end their lockdowns” (IEA, 2020a).

Food consumption

The food sector is also a major driver of greenhouse gas emissions. Food systems consist of a range of processes, namely production, transport, processing, packaging, storage, retail, consumption, loss, and waste of foodstuff (Mbow et al., 2019). The development of the current global food system, which is a major driver of climate change and has been increasingly vulnerable to it, dates back to the rapid growth in agricultural productivity since the 1960s (Mbow et al., 2019). In a little over five decades, global trade of crop and animal-sourced food increased by around five times (1961-2013) (FAOSTAT, 2018) and the anthropogenic greenhouse gas emissions associated with agricultural production has grown from 3.1 GtCO₂-eq per year in 1961 to 5.8 GtCO₂-eq per year in 2016, which represents an 87% increase (Mbow et al., 2019).

According to the UN Food and Agriculture Organization (FAO), the steady growing demand for agricultural products worldwide is mainly driven by population growth as well as increases in income and urbanization. This growing demand also reflects dietary changes in a context of economic growth, such as the increasing share of meat and dairy products and the reduction in the share of cereals in people’s diets (FAO, 2018: 16). Godfray et al. (2018) reveal that animal-based food, in particular meat, is the food with the greatest impact on the environment and in global emissions. FAO estimates that in order to feed the increasing world population food production has to increase by 50% until 2050 (FAO, 2018). This increase is necessary because growth in food consumption has been faster than population growth in the past two decades (European Commission, 2019a). This implies an increase in food consumption per capita, which has been characterized by two main factors, namely income growth and changes in consumer preferences. While the former leads to more overall food consumption, including high-value products such as meat and dairy products, the latter results from societal habits, health and environmental concerns (European Commission, 2019a; Mbow et al., 2019).

Despite the decades-long growth in food demand around the world, food insecurity and global inequalities in food consumption still persist. In 2018, FAO estimated that one in four people globally were moderately or severely “food insecure” (FAO, 2018). More recently, the agency reported an increased gender gap in accessing food and showed that prior to the COVID-19 outbreak, 8.9% of global population were undernourished (FAO et al., 2020). In addition, FAO highlighted that the pandemic places an additional 83 to 132 million people at severe risk of undernourishment (FAO et al., 2020). In light of this, while food insecurity still threatens a considerable part of world population, “overly rich diets represent a serious health issue for many of the world’s most affluent inhabitants and constitute a critical climate change driver” (Duro et al., 2020).

A recent study reveals that some of the household consumption options with the highest potential for climate mitigation include living car-free, reducing flying and food waste, shifting to a plant-based diet, and shifting to renewable electricity in the housing domain (Ivanova et al., 2020). Consequently, maintaining the current patterns of consumption negatively affects the prospects of deep decarbonization. Notwithstanding the numerous technological innovations and opportunities for sustainable consumption (Sanguino et al., 2020; TWI - The World in 2050, 2020; Ibn-Mohammed et al., 2021), continued “growth in demand, and therefore in production, largely absorbs the limited effect of technological and efficiency improvements and the incipient changes observed in consumption patterns” (Duarte et al., 2013; for the limited effect of technology advances in climate mitigation see also Li and Wang, 2017; Altıntaş and Kassouri, 2020).

So far, growing consumption implies an increase in absolute global emissions, inasmuch as there is no observable regulation available that requires low-carbon or low-resource standards for consumer goods. Some sustainability and ecological labels on food or household appliances provide incentives for climate-friendly consumption patterns, but perceived high prices, strong habits governing consumption, and other socioeconomic factors are important obstacles for low-carbon consumption patterns to become dominant (e.g., Rööös and Tjärnemo, 2011). Those labels eventually end up promoting a *green consumerism*, which maintains the logic of economic growth, while omitting the need for structural changes toward sustainable consumption and production (Boström and Klintman, 2008; Akenji, 2014).

Most national economies worldwide, their respective welfare institutions and the pacification of class conflicts and other social tensions still focus on economic growth (Boström, 2020). Despite the increasing attention given to norms, approaches, and protests claiming for climate justice or economic de-growth (Akbulut et al., 2019; Hickel, 2020; von Zabern and Tulloch, 2020), no changes are observed in the institutional conditions for mass consumption. The same is true for the enabling conditions for current consumption patterns. Recent studies suggest that disruptions such as the COVID-19 pandemic can alter individual behavior toward sustainable consumption patterns (e.g., Severo et al., 2021; Sun et al., 2021; Tchetchik et al., 2021) and that grassroots sustainability initiatives eventually support lower carbon footprints and the dissociation of consumption emissions from income and well-being (Vita et al., 2020). Yet, the persistent entanglement of identity and consumerism and of carbon-intensive everyday practices will continue to undermine the pathways toward decarbonization (Rööös and Tjärnemo, 2011; Engels, 2016), as long as the infrastructural conditions of consumption do not change. Likewise, it is more

likely that the disruptive changes caused by the COVID-19 pandemic will trigger rebound effects than that they will support decarbonization (see e.g., Wang et al., 2020 and Box 4).

Consumption patterns and the prospects of deep decarbonization by 2050

The ongoing pandemic may not fundamentally shift the consumption patterns of most of world population toward low-carbon products and services. The observed changes in energy, food and transportation consumption, and global emissions are expected to be temporary, while further transformations toward or away from decarbonization will depend on the responses to and the concrete outcomes of the current crisis (Beltermann et al., 2020; IEA, 2020d; Le Quéré et al., 2020). In countries like China (Chen et al., 2020), Denmark (Andersen et al., 2020), Germany (Sita et al., 2020), the United States (Baker et al., 2020), and Japan (Watanabe and Omori, 2020), the almost instantaneous increase in online consumption during the outbreak of COVID-19 indicates that it is the means by which consumer goods are acquired that has changed, but not the patterns of consumption. Last but not least, the expected population growth until 2050, mostly driven by developing countries with high potential of increasing overall consumption (UN, 2020), is likely to increase global greenhouse gas emissions. The Intergovernmental Panel on Climate Change (IPCC) estimates that without intervention in current food systems, global emissions might increase by about 30 to 40% by 2050 (Mbow et al., 2019).

Studies highlight the decarbonization potential of climate-related policy and regulation focused on changing consumption choices (e.g., Girod et al., 2014; Dubois et al., 2019; Khan et al., 2020), while others claim that government actions and economic incentives in response to the COVID-19 pandemic will likely influence the global emissions path for decades (Le Quéré et al., 2020). With regard to food systems, the *IPCC Special Report on Climate Change and Land* (2019) shows that there is more potential for climate mitigation in the production and distribution of goods and services side than in the consumption of healthy and sustainable products (2.3-9.6 GtCO₂-eq per year against 0.7-8.0 GtCO₂-eq per year) by 2050 (Mbow et al., 2019). This means that profound transformations in food production are necessary to reach deep decarbonization by 2050.

Whereas worldwide structural changes in the economic, transport, and energy systems are unlikely to happen in the short and medium term, the consequences of the COVID-19 crisis to climate action are yet not entirely clear. As Le Quéré et al. (2020) put it, “[t]he social trauma of confinement and associated changes [caused by the pandemic] could alter the future trajectory in unpredictable ways, but social responses alone [...] would not

drive the deep and sustained reductions needed to reach net-zero emissions.” Notwithstanding the current bottlenecks for ambitious climate change mitigation, post-crisis recovery plans that decouple socioeconomic development from high emissions can pave the way for low-carbon consumption patterns. Different national and international agencies have already issued a series of proposals for green recovery in the aftermath of the COVID-19 pandemic. In general, they advocate for investments and

structural reforms that enable strong decarbonization and other profound socioecological transformations (UBA, 2020b; UBA, 2020c; IEA, 2020c; UNEP, 2020a). It remains to be seen whether the enactment of climate-friendly laws, regulations, and infrastructures, along with societal pressure for ambitious climate action will occur and fundamentally change the current—and highly unequal—patterns of consumption worldwide.

8.9

Journalism

Driver description

This chapter assesses the role of professional journalism as a driver of decarbonization. The chapter will focus on journalism and not on other aspects of communication (e.g., social media, alternative sources of information, or interpersonal communication) because most research in climate change communication analyzes journalism (e.g., Schäfer and O’Neill, 2017), because professional norms, values, and routines can only be assessed for journalism, and because communication in general is too broad for a systematic assessment.

Although attacks on journalists and on the freedom of press have become more common around the world, journalism is widely regarded as the subsystem of society that reports and critically reflects on topics of societal interest in most modern democracies (McQuail, 2013). Professional journalists are those working in media organizations or for media organizations as freelancers, who generate content following a set of professional norms such as objectivity or autonomy, serving the public by providing information that is factually correct, new, and relevant (see e.g., Meier, 2007, for an overview). For many people, traditional journalistic media such as newspapers, radio, television, and their online counterparts on websites or apps are still the main sources they use to receive information about climate change (e.g., Guenther et al., 2020) or climate policy (e.g., Brüggemann and Engesser, 2017). Furthermore, much of the information in interpersonal conversations, in alternative online channels such as blogs, or on social media draws on or refers to journalistic coverage, provided on a multitude of offline and online channels.

Communication research has provided some evidence for links between journalistic media coverage and the perceptions, attitudes, and even behaviors of audiences (e.g., Arlt et al., 2011; Taddicken, 2013;

Ho et al., 2015)—even though this impact is mediated by the characteristics of the respective audience—particularly their prior attitudes and actions (see Bonfadelli and Friemel, 2017, for an overview of the research field of media effects). While the impact of single media messages is negligible, the cumulative impact of the sum of media messages received over time can shape how people see and act in the world (see Neverla et al., 2019, for a holistic view on the dynamics of our mediated media experiences of climate change). Journalism therefore has a strong potential to drive deep decarbonization, because of its role in agenda setting, framing of problems and solution spaces, and the quantity of media attention.

Observations of the current driver trajectory

There are several existing dynamics that may support deep decarbonization. First, media attention to climate change increased globally in the first decade of the 20th century (Schmidt et al., 2013). Long-term observations of media coverage of climate change indicate high levels of attention centered around some key events in the years 2006–2009, followed by a period of less journalistic attention, which only ended in 2018 and 2019 with the combination of hot, dry summers and the global youth movement for climate protection (Boykoff et al., 2020; Brüggemann and Sadikni, 2020).

There are distinct drivers of media reporting on climate change, and these have led to cycles of momentary increased media attention. Among those key drivers are international (scientific) events such as the annual UN Conferences of Parties (COP), the communication of single political, scientific, or activist actors, and extreme weather events (e.g., Schäfer et al., 2014). Since the future occurrence of these key drivers is almost certain, continued media

attention toward climate change is also guaranteed. However, the level of baseline media attention in the absence of such drivers is only around one percent of all articles published in leading news outlets internationally, and this baseline has not changed over time (Boykoff et al., 2020; Brüggemann and Sadikni, 2020).

Second, for a long time, the norm of balance in journalism provided an entry gate for climate change denial to be reported on in the news (Boykoff and Boykoff, 2004; Boykoff, 2007). However, there are indications of change away from neutrally balanced to interpretive climate reporting, giving rise to more evidence-based reporting (Brüggemann and Engesser, 2017; Merkley, 2020). While this might also be seen as supporting social dynamics toward deep decarbonization, in some cases journalistic news values (e.g., Guenther, 2020) still privilege conflict and extreme ideas, and thus give voice to fringe views in the debate about how to fight climate change (Brüggemann and Engesser, 2017). Thus, the journalistic focus on famous personalities (be it Greta Thunberg or Donald Trump) may sometimes deflect attention away from discussing the substance of climate policies.

Third, the way in which climate change is represented or framed in the media has also shifted. The *framing* (e.g., Entman, 1993 for a conceptual overview of framing) of climate change can either be described generically (the five frames of consequences, responsibility, conflict, human interest, and morality; see Dirix and Gelders, 2010) or topically (see Schäfer and O'Neill, 2017). While findings of individual studies vary, there is an overall recognition that climate change framing has changed from a distant scientific topic to a more concrete political, cultural, and specific topic (e.g., Metag, 2016). In addition, studies on framing effects have found that climate change messages can be more persuasive if they focus on the impact of climate change on public health (e.g., Maibach et al., 2010; Myers et al., 2012; Feldman and Hart, 2018). Furthermore, visual studies show that images of solutions and actions, and thus images that are non-threatening, invoke self-efficacy and motivation to act, because they often connect with everyday emotions and concerns (O'Neill and Nicholson-Cole, 2009; see also Feldman and Hart, 2018; for an overview, see Schäfer, 2020). Also, messages that focus on technological efficacy compared to curtailment (e.g., Nolan and Tobia, 2019), and messages that are framed in ways that are psychologically closer to the audience, for example in terms of time, space, and social relevance (e.g., Jones et al., 2017) can positively affect concern and engagement.

Nevertheless, there are also dynamics that may not support deep decarbonization. Media coverage interacts with other sources of information (e.g., advertising, public relations, interpersonal communication). For instance, most traditional and online media are offered as a package with advertising, so that journalistic calls for sustainable consumption

may go hand in hand with advertisements for environmentally harmful consumer goods, compromising the net effect of journalistic coverage on sustainable consumer behavior. Some researchers detect only small effects of media use on individual perceptions and behaviors (e.g., Taddicken, 2013). For example, the intensive reporting around the 2015 COP summit in Paris had only moderate effects on the knowledge and attitudes of audiences in Germany (Brüggemann et al., 2017). Some visual studies indicate that the most common pictures used to portray climate change in journalism—climate change impacts (e.g., extreme weather events) that are often associated with fear, distant scenarios, or politicians and celebrities (often at UN climate summits)—are either ineffective or invoke feelings of powerlessness and helplessness (O'Neill and Nicholson-Cole, 2009). Furthermore, even if media are persuasive, the effects of specific patterns of content are not universal across audiences (Nisbet, 2009). There is agreement among communication researchers that communication needs to be tailored to existing perceptions, values, and attitudes of different audience segments—including the audience segments *Alarmed*, *Concerned*, *Cautious*, *Disengaged*, *Doubtful*, and *Dismissive*—to make climate change more personally important and to motivate them to act (e.g., Leiserowitz et al., 2009; Metag et al., 2017). Moser (2010) advises that messages need to be internally consistent in all aspects, relatable to individuals, showing them solutions, while maintaining the audience's attention. However, recent research underlines that it is unlikely for media to reach all segments of the population equally, due to such phenomena as echo chambers (e.g., Walter et al., 2017), selective exposure (e.g., Feldman and Hart, 2018), and motivated reasoning (e.g., Druckman and McGrath, 2019). Most studies also report that politically rather conservative audiences show weaker or no effects when persuasive messages are tested, compared to rather liberal audiences (e.g., Feldman and Hart, 2018).

In summary, there are dynamics that both support and do not support deep decarbonization. The amount of media attention to climate change, how balanced media reporting on climate change is, and specific representations of climate change in the media can have an impact on audiences, and drive social dynamics toward or away from deep decarbonization, depending on how audiences engage with these messages. Hence, it depends on both the dominant messages conveyed and the audience segments who receive these messages.

Enabling and constraining conditions

Regarding journalism as a driver of decarbonization, there are several enabling and constraining conditions that support or undermine the driver's dynamics. Influences on journalistic content production are situated on different levels, including journalistic role perceptions and norms of individu-

al journalists, as well as organizational, institutional, and cultural contexts (e.g., Shoemaker, 1991).

For instance, there is strong engagement of professional journalists in leading news outlets for the issue of climate protection; in different countries, they form an interpretive community around the Intergovernmental Panel on Climate Change consensus (Brüggemann and Engesser, 2014). In addition, new types of specialized climate news providers have developed online. Science journalists are often enthusiastic about the institution and practice of science, and environmental journalists are inclined to be interested in environmental protection. Few journalists spread the outright denial of anthropogenic climate change, and those who do are often columnists without expertise in science reporting, who work in conservative or yellow press outlets (Brüggemann and Engesser, 2017). The decision of many media outlets to give more attention to the issue and framing of climate change (e.g., *The Guardian* in the UK, or *Die Tageszeitung* in Germany) can also be seen as an enabling condition on the organizational level—but editorial policies vary depending on ideological leaning of the newsroom and wider cultural and national political context in which media outlets are situated (e.g., Feldman et al., 2011).

However, there are constraining conditions as well. Journalism is about covering what is new, and thus focused on events (such as UN climate summits), providing for the neglect of long-term processes (e.g., Guenther, 2020), such as climate change. At the same time, conservative media seem to continue to attribute a more dismissive tone toward climate protection (e.g., Feldman et al., 2011) or neglect the issue as compared to more liberal media (Adam et al., 2020).

Furthermore, media environments have become contested terrains, largely because of the rise of digital media, that is, alternative channels on the internet and in social media (e.g., Brossard, 2013). As a result, funding cuts in traditional newsrooms have been made because the traditional business model of journalism has come under pressure (e.g., Levy and Nielsen, 2010; Peters et al., 2014). Another pressure on journalism results from the proliferation of online “news” sources and social networks, also opening new arenas for conspiracy narratives and the spread of misinformation around climate change (e.g., Fownes et al., 2018; Jones-Jang et al., 2019). Media environments are contested because many different actors seek to make their voices heard. For instance, stakeholders increasingly turn to the internet and social media to provide information and mobilize support (Schäfer, 2012). Communication on alternative channels on the internet is often not provided by professional journalists, but rather by amateur activists or professional science and industry public relations, or even NGOs (e.g., Brossard, 2013). Such communication is not effectively regulated; no professional gatekeepers are involved and thus no journalistic norms apply. We

have seen a crisis of the printed press as the traditional providers of science and environmental coverage for some time now (Dunwoody, 2014; Guenther, 2020), and this is not likely to change in the future. However, in new digital outlets, new jobs for specialized climate reporting have been emerging as well (Brüggemann, 2017).

In summary, there are both enabling and constraining conditions that can support or undermine driver dynamics toward deep decarbonization. Recent trends in science and environmental journalism have created a situation that is fundamentally open to future developments.

Current signs of change

The direction of this driver is currently changing. As outlined before, media attention to climate change is in a constant flux (Boykoff et al., 2020; Brüggemann and Sadikni, 2020), although we find that a certain amount of media coverage will always be guaranteed, due to continuous (media) events, future extreme weather events, and actors speaking up (e.g., Schäfer et al., 2014). A recent example of such shifts is the COVID-19 pandemic, which is seen as a disruption of the lately observed increase in media attention to climate change. Furthermore, we also believe that tendencies of the media to treat climate change in line with the media outlet’s political ideology (e.g., Feldman et al., 2011) may persist. Additionally, both the decreasing salience of (falsely) balanced climate reporting (Brüggemann and Engesser, 2017) and the framing of climate change (Metag, 2016; Schäfer and O’Neill, 2017) point in a positive direction at the moment, but the framing may change direction in the future, depending on future social dynamics such as the long-term social legacy of the current COVID-19 pandemic.

However, our assessment that the driver is changing is mostly related to the ongoing increasing importance of alternative and social media as sources of information regarding climate change for large parts of the audience, and hence sources that are not guided by professional gatekeepers (e.g., Peters et al., 2014). One might argue that journalism will at least for some audiences remain an important actor in the near future, in spite of struggles to find its new role in digital media environment (e.g., Guenther, 2020). But as of now, it is both hard to predict what role journalistic media will play in the future as well as what reporting on climate change after the COVID-19 pandemic will look like. Both these conditions are required for journalistic media to be effective in reaching parts of the audience. Hence, it is plausible that the driver remains important for future social dynamics, but its effect toward deep decarbonization is volatile.

Conditions for future change

Seven conditions seem particularly important to enable a journalism that more clearly supports social dynamics toward deep decarbonization.

(1) There needs to be ongoing media attention (e.g., Schmidt et al., 2013) to the climate change issue, preferably in both rather conservative- and rather liberal-leaning media (e.g., Feldman et al., 2011). In 2019, we observed that a high attention to the issue across a variety of different media was linked to the dominance of the issue on the public agenda (e.g., Guenther et al., 2020). An increased media attention is not in journalistic responsibility alone, but also depends on other social actors, who would need to continuously put climate change on the media agenda, through claim-making and actions that provide for journalistic news value, thus keeping a more continuous media attention on the climate change issue. Continued social pressure from civil society (such as Fridays for Future) but also, for example, socially engaged scientists, and established political actors might help keeping the issue on the agenda. Ungar (2014) refers to so-called *reporting opportunities*; although these opportunities are not equal globally but always embedded in specific cultural contexts, cross-national media agenda-setting (Pralle, 2009) helps explain how narratives move from one context to another.

(2) Reporting should avoid the norm of balance (Boykoff, 2007) that leads to an (over-)representation of voices of climate change denial; it should rather provide a more contextual and interpretive, or even evidence-based reporting (Brüggemann and Engesser, 2017).

(3) Contents of journalistic reporting can be framed in ways that motivate individuals to act, not as a distant and purely scientific topic but as a more concrete topic with relevance to everyday life (e.g., Metag, 2016), emphasizing more strongly health aspects of climate change because they seem to resonate with most people (e.g., Maibach et al., 2010; Feldman and Hart, 2018), using visuals of solutions and actions that are able to invoke self-efficacy and link to people's experiences and concerns (e.g., O'Neill and Nicholson-Cole, 2009; Schäfer, 2020), focusing on efficacy also on a textual level (e.g., Nolan and Tobia, 2019), and framing content as less psychological distant (e.g., Jones et al., 2017).

(4) Because media effects are not universal, specific messages need to be tailored to perceptions, attitudes, and behaviors of distinct audience segments (e.g., Leiserowitz et al., 2009; Nisbet, 2009), although one might fail to reach all audiences equally (e.g., Feldman and Hart, 2018).

(5) A stronger engagement of individual journalists (Brüggemann and Engesser, 2014) and professional online news providers (Brüggemann and Engesser, 2017) might shape both media attention and the specific contents into a more engaging perspective. Certainly, more journalistic expertise for both climate change, climate policy-making, and how media content is received by audiences is required.

(6) All these conditions can only be effective if journalism remains an important and trusted source of information for large parts of the audience, which would also be enabled by a better-resourced climate-journalism (e.g., financial support).

(7) At the same time, a stronger regulation of information on alternative channels and on social media might also help to counteract tendencies of echo chambers, selective exposure, or motivated reasoning (e.g., Druckman and McGrath, 2019).

Global resources provided by journalism

Journalism is a driver that interacts with all other social drivers assessed in this *Outlook*, to establish a social climate for change toward deep decarbonization. Journalism does not determine the other drivers but rather enhances already existing social dynamics. For instance, during UN climate summits, journalists have co-produced news with environmental NGOs (Lück et al., 2016). In addition, without intense media attention, Greta Thunberg's climate strike and Fridays for Future would probably have had much less of an impact on society. Particularly, established political elites closely monitor journalistic media outlets to detect public opinion and see how different ideas and actions find resonance in society (Pralle, 2009). Journalism's main resource is that it directs attention to certain problems or actors, to the detriment of other problems or actors. It makes certain frames salient and accessible to broad audiences, including certain recommendations for solving problems. Journalism may also help political elites to engage in climate protection by holding them responsible for their (in)action on climate change and keeping up the pressure established through past and ongoing global climate protests. However, journalism will be powerful only together with other actors.

In summary, despite the fact that the role of journalism is changing in general, the driver provides global resources by making information both visible and accessible. Events such as extreme weather, climate activism, social movements, but also information regarding all the other drivers can be reported in the media. In principle, journalism can—through its content—report on (and possibly enhance) all other social drivers, and thus potentially affect individual perceptions (e.g., of corporate responses), attitudes (e.g., support for climate protests), and behaviors (e.g., individual consumption patterns).

8.10

Knowledge production

Driver description

Knowledge production and climate change are entangled in two major ways. On the one hand, *diverse ways of knowing* (Schneegg, 2019; Box 3) shape the perceptions and understandings of climate change. On the other hand, diverse everyday experiences are constitutive for the processes of knowledge production in which climate change is identified to have social, political, and economic consequences. Against this backdrop, knowledge production becomes especially visible when actors seek to address these consequences through policies that define targets and instruments directed toward deep decarbonization. For the purposes of this assessment, the driver *knowledge production* refers to practices of knowledge generation and validation that provide facilitative capacities for envisioning and enacting transformations toward deep decarbonization. In order to retrace the trajectory of the driver, and mindful of the distinct impact of diverse ways of knowing, we operationalized the assessment of knowledge production by distinguishing between stages in the process of knowledge production which relate to different types of knowledge—background, scientific, and packaged knowledge—that come to fruition in distinct situations and at specific sites in the process of knowledge production. For example, as the most material of the three types, packaged knowledge is perceived to be especially tailored to align with specific political processes and policy-making, influencing for example the setting of specific emissions targets, providing reference for policy designs of emerging net-zero policies and corporate strategies as well as possible solution spaces in transition processes. At the same time, societal agents' use of packaged knowledge crucially depends on *competent performance* with regard to identifying extant scientific knowledge, and in turn, scientific knowledge rests on a wealth of invisible networks of background knowledge (Bueger and Gadinger, 2018).

Packaged knowledge describes intentionally assembled and tailored packages of knowledge, often strategically aligned with ongoing political and societal processes. The Intergovernmental Panel on Climate Change (IPCC) is the most prominent example for packaging efforts in institutionalized global environmental assessment. As these processes are often directly linked to political processes and play an important role in the political and societal debate on climate change, exploring these practices provides insights into the capabilities of and ways in which knowledge production can be regarded as a driver for deep decarbonization. In the context

of climate governance, international organizations like United Nations Framework Convention on Climate Change (UNFCCC), United Nations Environment Program (UNEP), domestic governments, and many other actors are involved in processes of mobilizing knowledge (Littoz-Monnet, 2017) and engaged in the processes of producing assessments by intergovernmental expert consensus (De Pryck, 2021). This consensus, or packaged knowledge, is co-produced by boundary organizations which facilitate between different social worlds of academic scholars, experts, policy-makers, and other societal agents (Gustafsson and Lidskog, 2018). International organizations apply different modes of knowledge mobilization: informing and guiding policy, legitimizing or depoliticizing action, substantiating policy positions, and minimizing institutional insecurity (Littoz-Monnet, 2017). Processes of mobilizing, producing, and validating knowledge are best understood as struggles (Kennedy, 2018) and contestations (Peterson, 2019), where power structures, inequalities (Hughes and Paterson, 2017), and epistemic geographies—the spaces of knowledge production and its circulation (Hulme, 2016)—are perpetuated and shape the results of packaging. The following sections situate packaged knowledge with reference to stages and types in the process of knowledge production.

Situating packaged knowledge in the process of knowledge production

Integrating a more nuanced understanding of knowledge production as a processual category is helpful in two ways. First, it is vital for the purposes of understanding knowledge production as a reflexive spatio-temporal process. Second, it offers an important empirical angle on the changing conditions of the political opportunity structure that frames this driver's effect on deep decarbonization. At the same time, knowledge production adds an all-important reflexive dimension vis-à-vis purely science-based assessments of knowledge that often remain partial to snapshot takes (Pierson, 2000) of what are otherwise evolving processes. To study the effect of this driver, it is therefore important to map conditions and practices of knowledge production (Oppenheimer et al., 2019; Schenuit et al., 2020) and to “zoom in on local sites” where affected stakeholders of climate governance are engaged in contestations (Wiener, 2014; Wiener, 2018b). We argue that in order to identify the possibilities and plausibilities of countering climate change based on deep decarbonization, studying this driver's

dynamics is key. To capture the driver's processual quality, we propose a three-stage approach that differentiates between three types of knowledge, that is, background, scientific, and packaged knowledge. Each type evolves in a distinctly contingent context which is differentiated with reference to stages of knowledge production. The three types of knowledge are closely interrelated. The differentiation is undertaken for analytical purposes. The following text details the types of knowledge with reference to the three stages of knowledge production, ranging from background knowledge as the most intangible toward packaged knowledge as the most material presentation of knowledge.

Background knowledge is typically identified by social scientists as a structural condition that is invisible to the uninformed viewer (Haraway, 1988; Wenger, 1998; Qin, 2018; Adler, 2019), but which has an enabling and/or constraining effect on action, nonetheless. At this most intangible stage, knowledge is not considered a driver in and of itself. The degree of materiality is low, and the use of this knowledge is intuitive and individual. However, background knowledge entails the normative *meanings-in-use* that are generated through every-day practice (Milliken, 1999; Wiener, 2009; Wiener, 2018b). It originates within a wider societal environment that is conditioned by the political opportunity structure on a given site, on the one hand, and by the larger process of globalization which extends beyond a polity, on the other. Therefore, knowledge production is a driver that is both enabled and/or constrained by the "rules of engagement" (Wiener, 2018b) of a given local opportunity structure, and in addition has a constitutive effect on these conditions. This matters for the process of knowledge production and its dynamics. The effect is demonstrated, for example, in our ongoing research on contested climate justice (not yet published), in which the empirical focus "follows the conflict" (Marcus, 1995) from conflicts about global climate norms (e.g., on topics of climate justice, decarbonization and so on) to local sites where these contestations take place (e.g., in the Arctic or in the Mediterranean). At these sites it becomes possible to account for plural representations of "situated knowledge" (Haraway, 1988).

Scientific knowledge cannot be treated as given knowledge. It is constituted through practice and it unfolds power in discursive practices of sense-making in which actors can refer and draw upon already generated knowledge resources on a particular issue (Brigg and Bleiker, 2010; Agar and Ward, 2018; Hamati-Ataya, 2018). Routinized practices make background knowledge visible (Bueger, 2014) and take shape in sets of skills specific within a field of work, for example scientific knowledge or agricultural knowledge. Scientific knowledge therefore identifies social facts, it adds specific meaning to everyday background knowledge and becomes more tangible as it materializes through sustained discursive interaction among actors, who develop

indicators, concepts and tools in order to observe and evaluate social, political or natural phenomena. For example, integrated climate models enable climate researchers to assess dynamics that indicate climate change. Climate modeling is a type of scientific knowledge that is centrally embedded in dynamics of sense-making among climate researchers and in climate governance.

The proposed focus on types of knowledge allows the retracing of knowledge production, because it captures the advancement of knowledge production from artefacts which are generated by practices and turn into intangible background knowledge (knowledge of/about) and into tacit scientific knowledge (knowing how). That is, it makes background knowledge tangible through the practice of scientific knowledge production, since this process is not an impartial or neutral dynamic. Instead, it is shaped by different political, cultural, or economic structures, by shared beliefs within given scientific communities (Brunnee and Toope, 2010), and by individual perceptions. At the same time, scientific knowledge constitutes the central resource for actors to identify climate change as a problem and to mobilize for specific solutions to tackle climate change, such as mitigation and adaptation policies (Corry and Reiner, 2020: 13). Thus, it connects the background knowledge of different actors with what is regarded as legitimate packaged knowledge. The Paris Agreement promotes the use of "best available science" as necessary to develop global responses to climate change (UNFCCC, 2015 Preamble, Article 4(1), Article 7(5) and Article 14(1)). However, dominant approaches in the field of economics are based on the notion of growth. These growth-based approaches in much packaged knowledge informs many climate policies and is severely contested by actors who claim that climate change can only be addressed through economic concepts, such as *de-commodification* and *de-growth* (e.g., Perkins, 2019).

Further contexts in which diverse ways of knowing are visible include indigenous initiatives such as in Nunavut, Canada, or various Arctic communities of young reindeer herders like the Iñupiat communities, who aim to combine traditional ways of land-use and climate change adaptation strategies. Hence, scientific knowledge is central in the societal perception of climate change and possible future solutions by building the link between the background knowledge of societal agents with the packaged knowledge that is outlined in policy-making. A central concern is that those societal agents whose knowledge counts as scientific are more likely to have a voice and therefore enjoy access to participation in the process of packaging knowledge. In the discursive production of packaged knowledge, the attribution *scientific* qualifies knowledge and underpins hierarchies regarding socially recognized knowledge. The outcome will shape which kind of scientific knowledge constitutes a global resource. This follows from the fundamental issue that all actors involved in global climate governance who

seek to legitimize and support specific climate policies, whether policy-makers or social movements, substantially rely on available scientific knowledge in order to assess, understand, and grasp climate change (Corry and Reiner, 2020).

Observations

Interrelated types of knowledge: background—scientific—packaged

The Paris Agreement, its targets, and the underlying knowledge production processes are prime examples for both envisioning and enacting the transformation toward deep decarbonization. Histories of the 2°C and 1.5°C global warming targets (Randalls, 2010; Guillemot, 2017; Livingston and Rummukainen, 2020) show the processes of co-production and mobilizing practices in the production of scientific and packaged knowledge.

The IPCC relies to a great extent on Integrated Assessment Models (IAMs) in the production of global environmental assessments that are aligned with political processes (such as the *Special Report on 1.5°C Global Warming*). IAMs themselves can be described as packaging practices, since their modeling assumptions often draw implicitly on background knowledge and explicitly on scientific knowledge in the form of climate science. Over the past years, IAMs have had substantial influence in envisioning transition pathways toward deep decarbonization in the climate debate and were—simultaneously—proactively influenced by political developments (Cointe et al., 2019; McLaren and Markusson, 2020; Robertson, 2020). Emerging international climate negotiations and climate science have long been interwoven (Jasanoff and Wynne, 1998; Jasanoff, 2004; Dahan-Dalmedico, 2008), mostly through boundary organizations like the IPCC (Beck and Mahony, 2018). Not only the final assessment products are considered to be influential for the emergence of the current climate regime (and vice versa), but also the assessment practices themselves in the run-up to their production (Oppenheimer et al., 2019). A recent example for this observation is the political compromise of the UNFCCC signatories to invite the IPCC to prepare a special report on the 1.5°C temperature target (Guillemot, 2017). Although the IPCC had close ties to the political process before, this was the first time that the IPCC has actually been asked to assess knowledge about a specific political target. The findings of the report, in return, substantially shaped political debates about net-zero-by-2050 targets. The report, with its roots in political negotiations, therefore illustrates the strategic mobilization and production of scientific knowledge in international climate governance. Its widespread influence on the climate debate, among youth protests, climate-related regulation, UN climate governance, and corporate action underlines its potential role as a key resource for other drivers toward deep decarbonization. There are, however, also pitfalls of these packaging practices. In the run-up to the preparation of the

IPCC report, scholars pointed to problematic incentive structures emerging in the scientific community through the assessment efforts (e.g., Hulme, 2016; Peters, 2016). Empirical observations of international climate negotiations show that the strategic packaging effort has—prior to and after the publication of the report—indeed been contested by some political actors (Aykut et al., 2020a).

In addition to the most prominent example of the IPCC, we observe a multiplicity of packaging efforts in the context of (international) climate policy-making. Among them are the *UNEP Emissions Gap Reports* that have been published in time with annual international UNFCCC negotiations to influence the debate and negotiations since 2010 (Christensen and Olhoff, 2019). Furthermore, there are packaging efforts that are less directly aligned with the political processes but are influential in the political and expert discussions as well, for example the annual International Energy Agency's *World Energy Outlook*. We observe that scientific reports—which are less institutionalized but also packaged in the sense of tailored and often strategically aligned with ongoing political and societal processes—are facilitated in cooperation between scientific experts and climate activists.

The example of temperature targets highlights that scientific knowledge is not uncontested within epistemic communities. Scientific knowledge is rather the object of ongoing debates about its utility and quality, which are—as shown above—not independent from the political context. Scientific knowledge production became a key part of this driver, as climate change is not only objectified but also imaginable to people within and outside academia. Recent discussions that emerged within the framework of the UNFCCC highlight the diversity of scientific knowledge in global society, for example, by establishing the Local Communities and Indigenous Peoples Platform. Such initiatives, however, have still very limited impact with respect to diversifying the knowledge base for global climate negotiations (Belfer et al., 2019). In fact, diverse ways of knowing become acknowledged most often when policy discussions revolve around measures for local communities (Barrett, 2013; McElwee et al., 2020). Diverse ways of knowing are usually scaled down to the local level but rarely gain access to global discourses on climate governance (Tucker, 2018).

Calls and efforts toward recognizing and upscaling indigenous and local knowledge to the global level in global environmental assessments, such as the IPCC reports (Obermeister, 2017), resulted in an increasing trend to engage with diverse ways of knowing in the IPCC. For example, over the past assessment cycles, there has been growing attention to acknowledge and integrate research on indigenous and local knowledge, especially in Working Groups II (Impacts, Vulnerability, and Adaptation) and III (Mitigation; Ford et al., 2016; Nakashima et al., 2018; Crate et al., 2019). An increased engagement with such knowledge systems can also be ex-

pected for the upcoming Sixth Assessment Report (Castán Broto et al., 2019). However, the available scientific literature that deals with indigenous and local knowledge has not been adequately assessed so far (Petzold et al., 2020) and the knowledge holders themselves are still not part of the assessment process (Obermeister, 2017). These limitations can be explained by the lack of expertise among authors about engaging with indigenous and local knowledge and knowledge holders (Ford et al., 2012) and the generally positivistic dominance of the IPCC, which hinders a further integration of non-scientific knowledge systems (Obermeister, 2017). If the procedural conditions in the IPCC continue to underrepresent diverse ways of knowing when framing the climate change problem, the solution space (Beck et al., 2014) and resulting policy guidance (Brugnach et al., 2014) will remain limited as well. The recent assessments by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) provide an example of how indigenous and local knowledge, as well as knowledge holders, have been increasingly and systematically involved in the assessment process itself, albeit only at an early stage (McElwee et al., 2020). The close link of IPBES to the IPCC system and recently established collaborations between the two reports, such as the upcoming joint expert meeting on biodiversity, may offer mutual learning opportunities about more inclusive assessment procedures.

In summary, despite observable dynamics to include diverse ways of knowing in packaged knowledge and global climate governance, three key issues persist and are contested by various actors around the globe. First, evidence on diverse ways of knowing remains a minor and insufficiently addressed part of IPCC assessments. Second, diverse knowledge holders themselves are still largely excluded from global climate assessments. Third, divergent perspectives on climate change implications are not transparently debated. All three issues indicate the often-noted research gap with regard to the impact and role of knowledge production in mitigating climate change (e.g., Chan et al., 2020).

Looking forward

Our observations indicate an increase in the relevance of knowledge production in shaping climate policy processes on the path toward deep decarbonization and an increase in the role of knowledge production as a resource of envisioning and enacting transitions toward deep decarbonization. The extent to which knowledge production will drive deep decarbonization is currently difficult to assess, but this first attempt to assess the driver's direction implies that it is currently insufficient to drive deep decarbonization by 2050. With a view to further research, we outline some current dynamics that are key in shaping the driver and in order to give an informed hunch about the limits and the support for the driver.

First, the growing and deepening of networks between climate activists and climate science became visible not only in performative terms with the claim “unite behind science”, but also through sustained cooperation, leading to new reports. A recent example is the creation of a report about how Germany is able to become CO₂-neutral (Wuppertal Institut, 2020). Fridays for Future activists and researchers joined forces to receive more attention by incorporating a scientific report into the repertoires of the social movement (Haunss and Sommer, 2020) and underpin with scientific knowledge previously made calls for more ambitious climate policy toward deep decarbonization. Publications from initiatives like Scientists for Future provide insights into how scientists themselves perceive their profession as a driver toward deep decarbonization. Environmental NGOs as well as fossil fuel industry actors (Shell, 2021) engage in the knowledge packaging practices and indicate the political relevance of packaged knowledge as a resource of the emerging global opportunity structure.

Second, two dynamics may undermine the driver toward deep decarbonization. On the one hand, diverse ways of knowing have difficulties in accessing dominant packaged knowledge. Alternative issues and problems related to climate change may not be heard, which could eventually challenge the legitimacy and credibility of packaging practices within political processes, at least for some actors. On the other hand, there are multiple efforts to undermine and counter packaged knowledge which supports deep decarbonization. The struggles linked to the rather politicized *IPCC Special Report on Global Warming of 1.5°C* is one of the most recent examples for this. This new attention for climate scientists raises the important questions of how the knowledge political actors unite behind is being produced, what forms of knowledge or actors are excluded, and which power structures and inequalities are inscribed in these processes. Given this dynamic, the uncertainties regarding ongoing packaging dynamics, and research constraints that come with the COVID-19 pandemic, the current assessment of this driver focuses on the way in which societal agents instrumentally mobilize and produce knowledge. Both mobilization and production of knowledge are crucial for developing further reflexive strategies to assess political implications in the future. In order to analyze the plausibility of climate futures, it is therefore key to conceptualize, understand, and retrace the impact of diverse ways of knowing (see Box 3).

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Glossary

This glossary focuses on key words in this and future *Hamburg Climate Futures Outlooks*. This includes existing definitions, for example, by the Intergovernmental Panel on Climate Change (IPCC), and concepts that are specifically defined in this *Outlook*.

Agency: The capability of individual and collective actors to formulate future aims and realize them in the present, even if only partially and with unforeseen outcomes (following Emirbayer and Mische, 1998), in the form of everyday social practices and individual decisions (Giddens, 1984; Tilly, 1984).

Carbon dioxide removal (CDR) (see also **Mitigation**): Anthropogenic activities removing carbon dioxide (CO₂) from the atmosphere and durably storing it in geological, terrestrial, or ocean reservoirs, or in products. It includes existing and potential anthropogenic enhancement of biological or geochemical sinks and direct air capture and storage, but excludes natural CO₂ uptake not directly caused by human activities (IPCC, 2018a).

Climate futures: Future joint developments of climate and society. Climate futures can be described through narrative scenarios. They include the physical climate system as a global system with regional manifestations and society as a complex multilevel system driven by divergent dynamics and strong moments of inertia (Chapter 1).

Climate sensitivity: The change in the annual global mean surface temperature in response to a change in the atmospheric CO₂ concentration or other radiative forcing (IPCC, 2018a).

Equilibrium climate sensitivity: Refers to the equilibrium (steady state) change in the annual global mean surface temperature following a doubling of the atmospheric carbon dioxide (CO₂) concentration. Since a true equilibrium is challenging to define in climate models with dynamic oceans, the equilibrium climate sensitivity is often estimated through experiments in Atmosphere-Ocean General Circulation Models (AOGCMs), in which CO₂ levels are either quadrupled or doubled from pre-industrial levels and which are integrated for 100–200 years. The climate sensitivity parameter (units: °C/(Wm⁻²)) refers to the equilibrium change in the annual global mean surface temperature following a unit change in radiative forcing.

Effective climate sensitivity: An estimate of the equilibrium global mean surface temperature response to a doubling of the atmospheric carbon dioxide (CO₂) concentration, which is evaluated from model output or observations for evolving non-equilibrium conditions. It is a measure of the strengths of the climate feedbacks at a particular time and may vary with forcing history and climate state, and therefore may differ from equilibrium climate sensitivity.

Transient climate response: The change in the global mean surface temperature, averaged over a 20-year period, centered at the time of atmospheric CO₂ doubling, in a climate model simulation in which CO₂ increases by 1% per year from pre-industrial conditions. It is a measure of the strength of climate feedbacks and the timescale of ocean heat uptake.

Deep decarbonization (see also **Net-carbon zero**): A global state of net-zero carbon emissions, achieved through the profound transformation of energy systems and steep declines in carbon intensity in all sectors of the economy (Deep Decarbonization Pathways Project, 2015).

Diverse ways of knowing: Diverse scientific or everyday practices and technologies for accessing the world, including different approaches within the same epistemic system, such as observations and models, and different epistemic systems, such as local, traditional, or indigenous knowledge systems (Box 3).

Enabling and constraining conditions (see also **Social drivers**): Driver-specific institutional, structural, and material environments that favor or inhibit driver dynamics toward a specific climate future (Section 4.2.1).

Feasibility: The degree to which climate goals and response options are considered possible and/or desirable. Feasibility depends on geophysical, ecological, technological, economic, social, and institutional conditions for change. Conditions underpinning feasibility are dynamic, spatially variable, and may vary between different groups (IPCC, 2018a).

Global opportunity structure: The repertoire of political, normative, and economic resources and constraints for global societal agency to move toward a specific climate future (Section 4.2.1).

Mitigation: A human intervention to reduce atmospheric CO₂ concentrations, involving emissions reduction or enhancing the sinks of greenhouse gases (IPCC, 2018a).

Net-carbon zero (see also **Deep decarbonization**): Net-zero carbon dioxide emissions are achieved when anthropogenic CO₂ emissions are balanced globally by anthropogenic CO₂ removals over a specified period (IPCC, 2018a).

Path dependency: The assumption that institution-building does not merely depend on interest-based decisions, but develops along a historical path that impacts future decisions. Path dependency may therefore also generate unintended consequences. The concept includes a range of social mechanisms that cause inertia, such as increasing returns in economic markets and technologies, as well as social institutions, organizations, routinized political processes, and discursive interventions. Notably, path dependency does not equal determinism; social change is neither impossible in principle nor inevitable after a certain threshold. For new paths to stabilize, they require self-reinforcing processes, but also continuous social, political, and discursive interventions (Section 4.1).

Plausible climate futures: The subset of possible future states that we expect to unfold with appreciable probability, given the existing evidence from the physical and social worlds (see Chapters 1 and 2).

Possible climate futures: We understand possible climate futures as those future states that are consistent with our joint understanding of climate and social dynamics (Chapter 1).

Probability: A statistical description of how likely an event is thought to occur or will occur.

Scenario: Scenarios are descriptions of potential evolutions of the world, such as climate futures (Chapters 3 and 4).

Social drivers: Overarching social processes that generate change toward or away from a given scenario and its characteristics (Chapter 4).

Synergy (see also **Trade-off**): Synergies arise when striving for one desirable goal also has positive effects on another (see also IPBES, n.d.).

Trade-off (see also **Synergy**): A trade-off is a situation in which an improvement in the status of one aspect of the environment or of human well-being is necessarily associated with a decline in or loss of a different aspect. Trade-offs characterize most complex systems, and are important to consider when making decisions that aim to improve environmental and/or socio-economic outcomes (IPBES, n.d.).

Transformation: A change in the fundamental attributes of natural and/or human systems (IPCC, 2018a).

Frequently asked questions

FAQ 1: What does CLICCS mean by “climate futures”?

How will our lives and those of coming generations change under the conditions of a changing climate? What climate and what types of societies will shape human existence in the coming decades? The Hamburg Cluster of Excellence Climate, Climatic Change, and Society (CLICCS) investigates *climate futures*, defined as potential future developments of the combined physical and social systems. The social and the physical systems are closely interlinked. Societal developments, for example, determine the extent of greenhouse gas emissions, which drive changes in the physical climate system. In turn, climate change affects living conditions on Earth. With a multidisciplinary perspective, CLICCS aims to improve the scientific understanding of which climate futures are possible and which are plausible.

FAQ 2: What are possible and plausible climate futures?

The *Hamburg Climate Futures Outlook* presents a novel attempt to distinguish between possible and plausible climate futures. *Possible* climate futures are those that are consistent with the scientific understanding of the climate system and social dynamics. *Plausible* climate futures denote the subset of those possible future states that we expect to unfold with appreciable probability, given the existing evidence from the physical and social worlds (see Figure 1). Natural sciences evaluate plausibility in light of physical laws and rules of cause and effect. Social sciences can provide conjectures about plausibility that build on understandings of how social systems change and also how they resist change. By bringing together knowledge from different fields to assess which futures are plausible, CLICCS helps to narrow down the multitude of future scenarios, in order to inform political and individual decision-making.

FAQ 3: How does CLICCS assess the social plausibility of climate futures?

To assess the plausibility of certain climate futures, CLICCS scientists developed the Social Plausibility Assessment Framework, a methodology that captures key aspects of climate-related transformations, including crucial drivers of societal dynamics, their enabling and constraining conditions, and observed changes in these drivers and conditions. Based on this, a conjecture about the plausibility of specific climate futures is derived.

In the 2021 *Hamburg Climate Futures Outlook*, the methodology is applied to answer the guiding research question: Is it plausible that the world will reach deep decarbonization by 2050? Deep decarbonization describes a net-zero balance of carbon dioxide emissions, where the amounts of emitted and absorbed carbon dioxide approximately cancel. The following social drivers of decarbonization are examined as part of this assessment: United Nations climate governance, transnational initiatives, climate-related regulation, climate protests and social movements, climate litigation, corporate responses, fossil fuel divestment, consumption patterns, journalism, and knowledge production.

FAQ 4: What evidence does the Social Plausibility Assessment Framework provide for achieving deep decarbonization by 2050?

According to the social plausibility assessment conducted for the 2021 *Hamburg Climate Futures Outlook*, there is only sufficient evidence to support the plausibility of a partial decarbonization by 2050. The observed dynamics of the social drivers are currently inadequate to bring about the rapid, wide-ranging social transformations that would be needed to achieve deep decarbonization by 2050. However, the social plausibility assessment also indicates which changes could make such a future plausible. Actors from different fields shape a range of political, normative and economic resources—the *global opportunity structure*—that are able to influence social processes worldwide. This structure is flexible and provides essential elements for societal transformations toward a specific climate future scenario, such as deep decarbonization by 2050.

International climate governance initiatives, for example, provide opportunities for the establishment of political agreements and norms as well as the production and communication of crucial knowledge. Climate litigation, social movements, and journalism are able to mobilize wider support for climate action. Regulations and corporate decisions can further strengthen the process. Such change builds on four main conditions: the global momentum for climate action, the implementation of climate-friendly laws, policies and infrastructures, the combination of societal pressure and inclusion of deep decarbonization in political agendas, and fossil fuel divestment and financial support for climate change mitigation.

FAQ 5: Are the very low and the very high emissions scenarios used in current climate models plausible?

The major scenario frameworks in use have been created without intentions to develop probabilistic interpretations. They aim to describe a variety of development pathways and their implications, but cannot be interpreted as forecasts or predictions.

To improve information for climate change mitigation and adaptation planning, CLICCS assesses whether very low and very high CO₂ emissions scenarios are plausible from social-dynamic and techno-economic points of view. Very low emissions scenarios that would maintain global warming below 1.5°C rely on negative emissions—the active removal of carbon dioxide from the atmosphere. However, some evidence speaks against the plausibility of implementing the necessary technology at a sufficient scale. The social plausibility assessment also finds that there is currently insufficient societal momentum to drive the rapid emissions cuts necessary for the very low emissions scenario. On the other hand, global warming in the high emissions scenario is thought to cause damages and consumption losses that would slow down economic growth and, as a consequence, limit potential emissions. The falling cost of clean energy and limitations on recoverable coal reserves could also prevent the high emissions necessary for this scenario. According to these lines of reasoning, the very low and the very high emissions scenarios are currently not plausible.

FAQ 6: How do climate change mitigation goals and other sustainable development goals interact and how might this influence plausible climate futures?

Climate change adaptation, mitigation, and sustainable development goals sometimes come into conflict with one another, but sometimes they also support each other. These situations are described respectively as *trade-offs* and *synergies*. While the *IPCC Special Report on Global Warming of 1.5°C* sees fewer challenges for climate change mitigation in scenarios that also emphasize sustainable and equitable development, newer literature highlights potential trade-offs between mitigation strategies, which include large-scale negative emissions technologies, and food security or biodiversity protection.

Deep decarbonization scenarios become more plausible if there are synergies between the Sustainable Development Goal (SDG) 13 *Climate Action* and other SDGs. However, synergies and trade-offs play out differently in different contexts and on different time scales. For example, cities are on the front-line of climate change mitigation and adaptation, and present many challenges in the form of trade-offs. Decentralized settlement makes cities more climate-resilient—but it also increases land use and infrastructure needs, and, as a consequence, increases greenhouse gas emissions. Denser cities, on the other hand, help reduce internal material and energy demands and therefore support climate change mitigation—but this also creates new dependencies between cities and their hinterlands.

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