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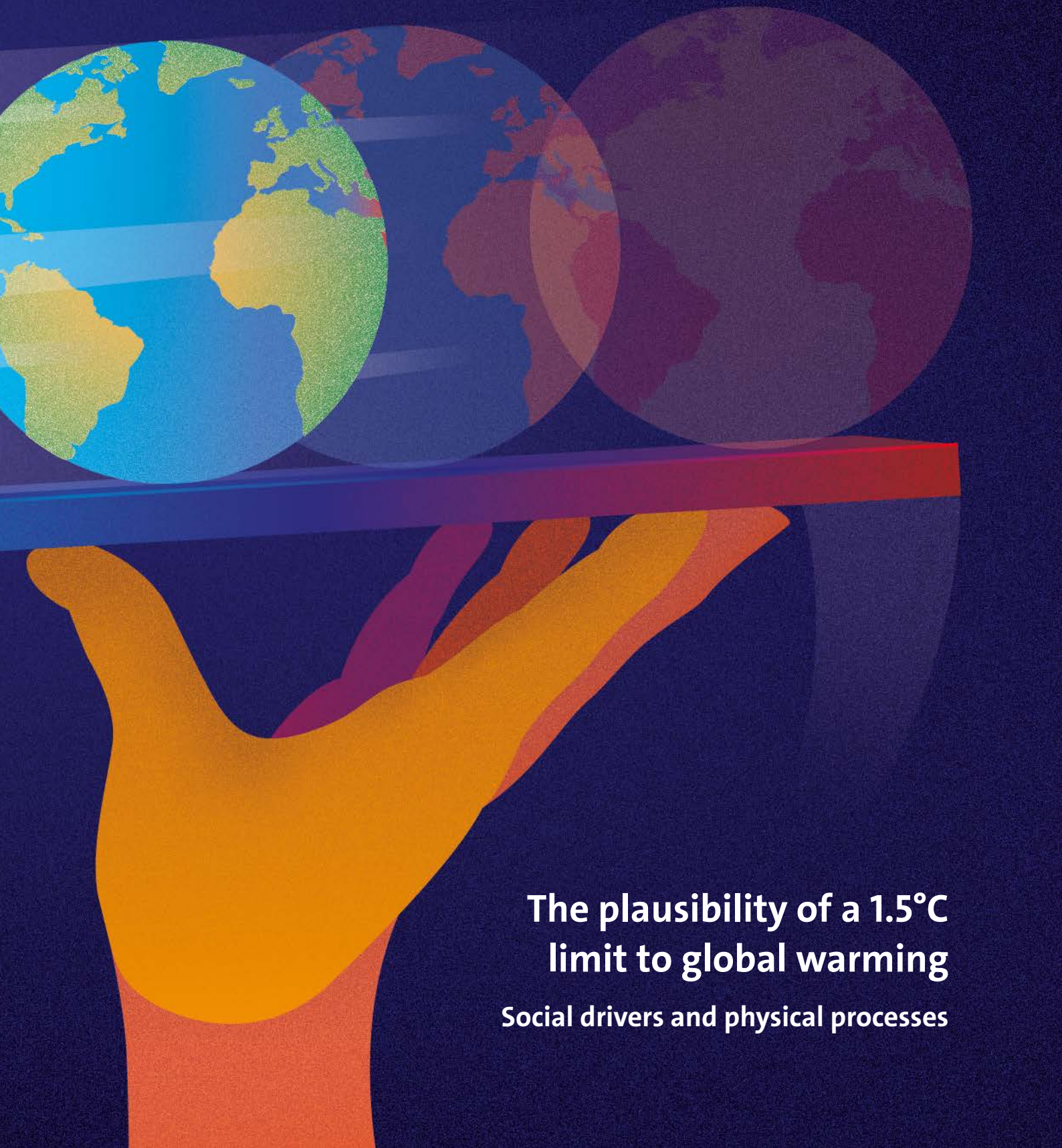
HAMBURG CLIMATE FUTURES OUTLOOK



The plausibility of a 1.5°C limit to global warming

Social drivers and physical processes

3

Plausibility of attaining the Paris Agreement temperature goals

This chapter synthesizes the main findings of the social and physical plausibility assessments (Chapter 6) with regard to the climate future scenario of this Outlook, which includes the achievement of deep decarbonization by 2050, and the attainment of the Paris Agreement temperature goals (Section 2.1.3). The social drivers analyzed in Section 6.1 are nearly the same as in the 2021 Outlook edition, namely UN climate governance, transnational initiatives, climate-related regulations, climate protests and social movements, climate litigation, corporate responses, fossil-fuel divestment, consumption patterns, and knowledge production. Journalism as a driver has been broadened to cover journalism and social media and is now called media. The physical processes assessed in Section 6.2 are permafrost thaw, Arctic sea-ice decline, polar ice-sheet melt, Atlantic Meridional Overturning Circulation (AMOC) instability, Amazon Forest dieback, and regional climate change and variability. Section 3.1 explores the current trajectory, the enabling and constraining conditions, and the emergent dynamics of key social drivers of decarbonization. Section 3.2 reports past and current changes in select physical processes of public interest, their mutual influences, and their potential to support or inhibit the attainment of the Paris Agreement temperature goals. Section 3.3 looks into interactions between the social and the physical domains, and Section 3.4 discusses implications of failing to stay within the climate goals addressed in this Outlook. Finally, Section 3.5 highlights fundamental conditions and resources for future change to a net-zero world.

The following sections are all based on information provided either in Tables 1 and 2 (which summarize the findings of the social and physical assessments with regard to the respective guiding questions) or in the individual assessments in Chapter 6. In the latter case, cross-references to the specific sections are provided. For ease of reading, we do not here include the extensive references to the literature reviewed, since they are given in detail in the individual assessments in Sections 6.1 and 6.2.

3.1

The plausibility of deep decarbonization by 2050

In the 2021 Outlook edition, we found that deep decarbonization by 2050 is not plausible, although the dynamics of many social drivers do support transitions to partial decarbonization (Stammer et al., 2021b). We differentiate between *decarbonization* and *deep decarbonization*. The former refers to the process of stopping or reducing greenhouse gas emissions, not necessarily linked to specific time-bound goals or climate future scenarios. Deep decarbonization, in turn, is defined as both a change process and a qualitative scenario that entails wide-reaching social transformations to net-zero carbon emissions by 2050 (Held et al., 2021; Section 2.1.3). In other words, deep decarbonization refers to large-scale change at the necessary speed for the attainment of global climate mitigation goals, such as limiting global warming to 1.5°C (Section 2.1.3).

The updated social plausibility assessments (Section 6.1) indicate that, as in the 2021 Outlook edition, none of the ten social drivers support deep decarbonization by 2050 (Figure 3). The current trajectory of seven social drivers (i.e., UN climate governance, transnational initiatives, climate-related regulation, climate protests and social movements, climate litigation, fossil-fuel divestment, and knowledge production) supports decarbonization but not deep decarbonization. The internal dynamics of these drivers are particularly influenced by the persistence of ambition, implementation, and knowledge gaps. The dynamics of two other social drivers (i.e., corporate responses and consumption patterns) continue to substantially undermine the pathways to decarbonization, let alone deep decarbonization, despite an increasing number of sustainability initiatives,

net-zero targets, and the growing deployment of renewable energy in different parts of the world. One driver (i.e., media) remains ambivalent insofar as its dynamics are volatile, sometimes supporting and sometimes undermining deep or partial decarbonization, depending on the framing of information and on whether and how media organizations and platforms provide visibility to climate impacts and action. In short, while seven out of ten social drivers currently support decarbonization, their enabling conditions are insufficient for reaching worldwide deep decarbonization by 2050. Note that the dynamics of virtually all social drivers of decarbonization have been and continue to be significantly affected by the short-, medium-, and long-term consequences of the COVID-19 pandemic and Russia's invasion of Ukraine (Table 1). With regard to the latter, it is still unclear whether in the long term the conflict will lead to or undermine worldwide efforts to reduce dependence on fossil fuels and to accelerate energy transitions (Box 3).

Enabling and constraining conditions of social drivers of decarbonization

The dynamics of the analyzed social drivers point to interconnected enabling and constraining conditions for the drivers to support deep decarbonization by 2050. For instance, journalism and social media platforms fulfill different roles in the climate debate, not only supporting climate action but also promoting anti-science agendas. Another example relates to ambivalent dynamics of knowledge production. Packaged knowledge, regarded as the most tangible type of knowledge production (Section 6.1.10), provides societal actors with global climate data that informs decision-making processes. However, packaged knowledge may be a constraining condition for knowledge production to support deep decarbonization if the packaged knowledge fails to integrate diverse ways of knowing required for socially just transitions to deep decarbonization.

Social drivers' enabling and constraining conditions may also vary in terms of timescale. On the one hand, long-term expectations with regard to profitability and security of continued fossil-fuel investment as well as ongoing and envisioned political regulations, investment flows, and technological advancements can either enable or constrain the dynamics of social drivers toward deep decarbonization. This depends, among other things, on companies' perceptions, market-based institutional developments (e.g., competition, consumption patterns), and political decisions and prioritization amid expected future scenarios. On the other hand, current (geo)political conflicts and circumstances also substantially influence the dynamics of social drivers of decarbonization. For example, the election of governments committed to climate action in Australia, Brazil, Chile, Germany, and the US is an enabling condition for social drivers' dynamics toward deep decarbonization (e.g., UN climate governance and transnational initiatives), but disruptive events such as Russia's invasion of Ukraine pose a series of challenges for decarbonization at multiple scales of governance.

The social driver assessments indicate that there are key enabling conditions for the drivers to support deep decarbonization by 2050. These include some of the social drivers themselves (UN climate governance, climate protests and social movements, climate litigation, climate-related regulation) and interconnections among them (e.g., synergies between knowledge production, social movements, and climate litigation). Growing scientific evidence, public interest, and media coverage regarding climate impacts support the dynamics of climate litigation, climate protests, and social movements. Access to justice and fundamental legal norms are also key enabling conditions for these social drivers to support deep decarbonization. Knowledge production and the expansion of strategic litigation networks, social movements, and transnational initiatives for climate action support the dynamics of UN climate governance and corporate responses to the implementation of ambitious climate mitigation policies. The rise to power of governments committed to climate protection is also an enabling condition for social drivers to support deep decarbonization. Investors' long-term expectations that fossil fuels will eventually become unattractive assets, and strong support from large companies' top management for decarbonization goals and climate mitigation policies are key enabling conditions for fossil-fuel divestment and corporate responses to climate change.

Notwithstanding the wide range of observable enabling conditions, the social plausibility assessments also highlight critical constraining conditions for the drivers to support deep decarbonization. These include the hegemony of growth- and fossil-fuel-based political and economic systems, which rely on massive, uneven, and unsustainable consumption patterns. Despite the numerous proposals for green recovery in the context of the COVID-19 outbreak, recovery programs and measures to relieve the socioeconomic impacts of the pandemic have been locked in fossil-fuel dependence. Structural challenges, such as extreme social inequalities and persistent implementation gaps and knowledge gaps, also significantly undermine the dynamics of social drivers toward deep decarbonization. Another constraining condition is the reliance of transnational initiatives and corporate responses on a market logic at the expense of (national) regulatory frameworks that support the implementation of key institutional arrangements for climate mitigation, such as ambitious target design, monitoring and reporting obligations, third-party auditing, and enforcement procedures. In addition, the call of social movements for more climate action is often counteracted by public demand for subsidies to reduce the price of fossil fuels. The

assessment also shows signs of societal backlash against climate action (e.g., emergence of anti-climate governments and lobby groups, conservative majority in supreme courts), a lack of political authority to regulate greenhouse gas emissions, and challenges for journalism to communicate scientific findings. These challenges include competition among sources of information, politically conservative powerful media organizations, and social media (especially far-right fringe media) as a destabilizing factor.

Social drivers' dynamics and the plausibility of the scenario

We observe numerous changes in the dynamics of the social drivers of decarbonization, but most of them are only incremental or temporary. The United Nations Framework Convention on Climate Change (UNFCCC), especially through its Conference of the Parties (COP), continues to provide strategic arenas for the establishment of climate action pledges and initiatives, which nevertheless remain insufficient and uncertain, among other things due to climate finance obstacles. At the same time, the substantial increase in transnational initiatives over the last years has facilitated the coordination of numerous societal actors (e.g., business, and regional and local governments) toward upgrading their ambition to align with the Paris Agreement and toward strategic shifts for the implementation of net-zero emissions pledges. The rise to power of climate-action-friendly governments and the increasing number of pro-climate lawsuits in the US and the EU support the dynamics of other social drivers such as UN climate governance, climate protests and social movements, and climate litigation. We expect cases of climate litigation to grow in number and to increasingly target companies in the fossil-fuel industry and beyond. It is plausible to assume that the conservative majority in the US Supreme Court will slow down climate litigation in the country but not necessarily elsewhere.

Climate protests and social movements, which became key players in climate-related political processes in recent years, have regained momentum since COVID-19 restrictions were lifted. Climate protests have given growing importance to the climate justice norm, which in turn increases media and public interest in climate policies that may have positive effects on decarbonization. Nevertheless, Russia's invasion of Ukraine and its implications have captured media and public attention and have led societal actors to focus on short-term solutions for political and socioeconomic crises at the expense of radical shifts necessary for climate neutrality. Russia's aggression has been perceived by many as an opportunity for high-emitting Western countries to decrease dependence on fossil fuels and, thereby, for faster energy transitions and shifts toward decarbonization. In this context, social movements and strategic litigation networks have new arguments to demand bolder climate action. On the other hand, just like in the context of the COVID-19 pandemic, Russia's aggression is expected to lead to further locking in of new fossil-fuel dependencies. Another consequence of Russia's invasion of Ukraine is the tendency to securitize climate policy—that is, for climate-related policymaking and discourses to portray climate change mostly in terms of international or national security.

Russia's invasion of Ukraine and the crisis of the international order substantially undermine multilateral cooperation on climate change. Amid deep uncertainties and the risk of conflict escalation, context conditions for social drivers—especially UN climate governance, corporate responses, and fossil-fuel divestment—to support decarbonization became even more challenging, and the risk of a backlash against climate mitigation norms and practices is high. Significant gaps in the implementation of climate-related regulation are expected to persist for several years to come. Companies and governments around the world continue to plan for massive investments in fossil fuels. Rising energy demand and energy price developments are expected to undermine fossil-fuel divestments, because they guarantee that the profitability of fossil-fuel engagements continues to be high, at least in the short term. Hence, despite the growing number and volumes of fossil-fuel divestment, the dynamics of this social driver are not strong enough to prevent new investments into fossil fuels.

The dynamics of two key social drivers of decarbonization (i.e., corporate responses and consumption patterns) continue to significantly undermine global deep decarbonization efforts. Notwithstanding the recent trends of adopting net-zero pledges and science-based targets, the majority of companies still do not respond in great depth to the current challenges and expected impacts of climate change. Global consumption patterns continue to be highly carbon-intensive, and the incremental changes observed during the pandemic proved temporary. Increasing gains in energy efficiency, the decoupling of emissions from economic growth in developed countries, and incipient changes toward low-carbon consumption around the world have been insufficient in supporting the dynamics of this social driver toward decarbonization. These processes will likely continue to be nullified by the continued growth in demand and production of (new) carbon-intensive goods and services. High consumption levels and their environmental impacts are driven in particular by affluent consumers, who represent a very small portion of the world population. Structural challenges—such as persistent extreme social inequalities, carbon-intensive consumption patterns, and fossil-fuel lock-ins—push the dynamics of these and also other social drivers away from decarbonization.

Overall, the updated conjectures of social driver assessments show that achieving deep decarbonization by 2050 remains not plausible. This means that, without considerable changes in social drivers' dynamics in the next years, it is not plausible that the world will witness the rapid emissions reductions required to attain the Paris Agreement temperature goals.

3.2

Physical processes of public interest and their effect on the plausibility of attaining the Paris Agreement temperature goals

The assessments in Section 6.2 consider the influence of six physical processes of public interest on global surface temperature and deduce their potential in affecting the plausibility of attaining the Paris Agreement temperature goals. This is done by considering changes in physical and biogeochemical properties due to warming and their effect on global surface temperature or on the carbon cycle. Although we are aware of the fundamental role of the Planck temperature response in stabilizing the global climate (Box 2), we assess whether other physical processes also enable or constrain temperature goals with increasing global warming levels.

Past evolution of physical processes and their interaction

The past and current increase in global surface temperature clearly affects elements of the Earth system, such as permafrost, Arctic sea ice, and the Amazon Forest. The warmer climate has resulted in a significant warming of permafrost in the past 30 to 50 years and in an increase of abrupt permafrost thaw phenomena such as thermo-erosion or thermokarst. Observations show that there is only limited evidence of increases in annual CO_2 and CH_4 emissions from permafrost. Polar regions are witnessing a rapid linear decline of the Arctic sea ice, which shows no sign of having a tipping point, and a substantial loss of ice mass from the Greenland and Antarctic Ice Sheets. The latter is expected to become the dominant source of global mean sea level rise. Changes in the polar vortex, storm tracks, jet stream, and planetary waves—which can affect the frequency, intensity, duration, seasonality, and spatial extent of weather extremes—have been observed. Weather extremes such as droughts and floods are becoming more frequent and more intense in the Amazon Forest. The combination of deforestation, forest degradation, and changes in precipitation have resulted in the reduced resilience of the Amazon Forest and a decline in the carbon sink. The Atlantic Meridional Overturning Circulation (AMOC) is expected to become weaker because of global warming; however, it is not clear whether such a weakening is already taking place because of too short time series of direct observations, uncertain longer-term reconstructions, high interannual variability, and the disagreement between model simulations and observations (Section 6.2.4). Except for the uncertainties about the AMOC weakening, all selected processes are clearly affected by the warming climate.

The elements and processes of the climate system influence each other (Table 2 and Section 6.2). Additional freshwater input from melting polar ice sheets into the ocean can affect global ocean circulation and the corresponding transport of heat, which is also largely affected by the strength of the AMOC (Sections 6.2.3 and 6.2.4). This in turn affects the Arctic sea-ice decline, which is connected to changes in oceanic heat transport (Section 6.2.2), the stability of the Greenland Ice Sheet in the case of weaker northward heat transport due to an expected slowdown of the AMOC with climate warming (Section 6.2.4), and the instability of the Antarctic Ice Sheet due to an accumulation of heat in the Southern Ocean (Sections 6.2.3 and 6.2.4). In some cases, changes in the dynamics of physical processes can lead to regional climate change (Section 6.2.6), as is the case for permafrost thaw, which affects high-latitude cloud cover and has uncertain consequences for precipitation patterns in the Arctic region (Section 6.2.1). Some processes also have the potential to influence climate in other regions of the planet. For instance, a potential substantial slowdown of the AMOC could have a severe impact on the global hydrological cycle and weather patterns (Section 6.2.4)—such as

triggering a dieback of the Amazon Forest by shifting the tropical rain belt southward and changing precipitation patterns (Sections 6.2.4 and 6.2.5). Indeed, changes in the AMOC, extreme weather events, and a warmer North Atlantic could lead to a drier Amazonia with large consequences for regional ecosystems and the carbon cycle (Section 6.2.5). On the contrary, due to contrasting views, it is uncertain whether Arctic sea-ice loss plays a substantial role in modifying weather patterns in other regions (Section 6.2.2).

Effect on the plausibility of attaining the Paris Agreement temperature goals

The assessments in Section 6.2 analyze the effects of climate change on the physical processes, on global surface temperature, and on the carbon cycle. By extrapolating current trends, permafrost thaw and Amazon Forest dieback are expected to release somewhat more than one year's worth of today's anthropogenic CO_2 emissions between now and 2050. Thus, the contributions of these two processes to the remaining carbon budget are small. Since both will only moderately affect the global surface temperature, we deduce that they also only moderately inhibit the plausibility of attaining the Paris Agreement temperature goals (Figure 3). The expected slowdown and potential collapse of the AMOC would also lower the prospects of attaining the Paris Agreement temperature goals, because less heat and CO_2 would be removed from the atmosphere (Figure 3). By contrast, the melting of the Greenland and Antarctic Ice Sheets and the Arctic sea ice barely affect the global surface temperature. They consequently do not affect the plausibility of attaining the Paris Agreement temperature goals (Figure 3). This plausibility is also not affected by regional climate change and variability since changes in mean climate and extremes will be either amplified or attenuated by internal variability (Figure 3). Under increased global warming, internal variability will co-determine the frequency and intensity of extreme events on a regional scale.

3.3

Integrative effects on the plausibility of attaining climate goals

Jointly assessing social and physical plausibility of climate futures is essential for grasping the extensive interactions between the social and physical worlds. The assessments in Chapter 6 support the integrative approach by providing examples with regard to the prospects of attaining the Paris Agreement temperature goals through deep decarbonization. To combine social and physical aspects we consider social-ecological systems in the integrative concept of humans-in-nature (as in Chapter 4).

Ecosystem changes, cultural practices, and legal rights: Warming climate and changes in the physical boundary conditions (e.g., permafrost thaw, weather extremes, and Arctic sea-ice decline) induce changes in social-ecological systems around the world. The changes have serious impacts on local ecosystems, forest resilience, and wildlife, and they affect, among others, settlements, critical infrastructures, communities, and human well-being. For example, livelihoods, health, and food security of Indigenous Peoples in the Arctic, as well as cohesion of these communities, their self-determination, and identity are connected to cultural practices that depend on sea-ice cover, ice-dependent species, and permafrost (Sections 6.2.2 and 6.2.1). Another example is that sectors like agriculture, fishery, and tourism are adapted to the regional climate but face various challenges if the climate variability communities are adapted to are exceeded (Section 6.2.6). Effects on both social and ecological aspects have resulted in societal transformation that supports the path toward climate goals. Examples are, first, an increase in climate litigation practices by Indigenous communities and communities throughout the Global South and, second, legal cases that go beyond human rights-based arguments and acknowledge the rights of nature (Sections 6.1.5 and 6.1.4). Both are supported by media, social movements, and diverse ways of knowing.

Climatic change, economic opportunities, and political regulation: Some economic opportunities—both new (e.g., increased maritime trade, commercial fisheries, cruise ship tourism, and offshore hydrocarbon and mining operations in an ice-free Arctic Ocean; Section 6.2.2) and established ones (e.g., land-use change in the Amazon Forest)—exhibit motions away from a climate future scenario in which global temperature is limited to 2°C and, if possible, to 1.5°C. However, the decision of the International Maritime Organization member states to tax fossil fuels in the shipping industry is an important first step toward decarbonizing the sector (Section 6.1.1). Further, the new Lula da Silva presidency in Brazil promises a policy shift toward

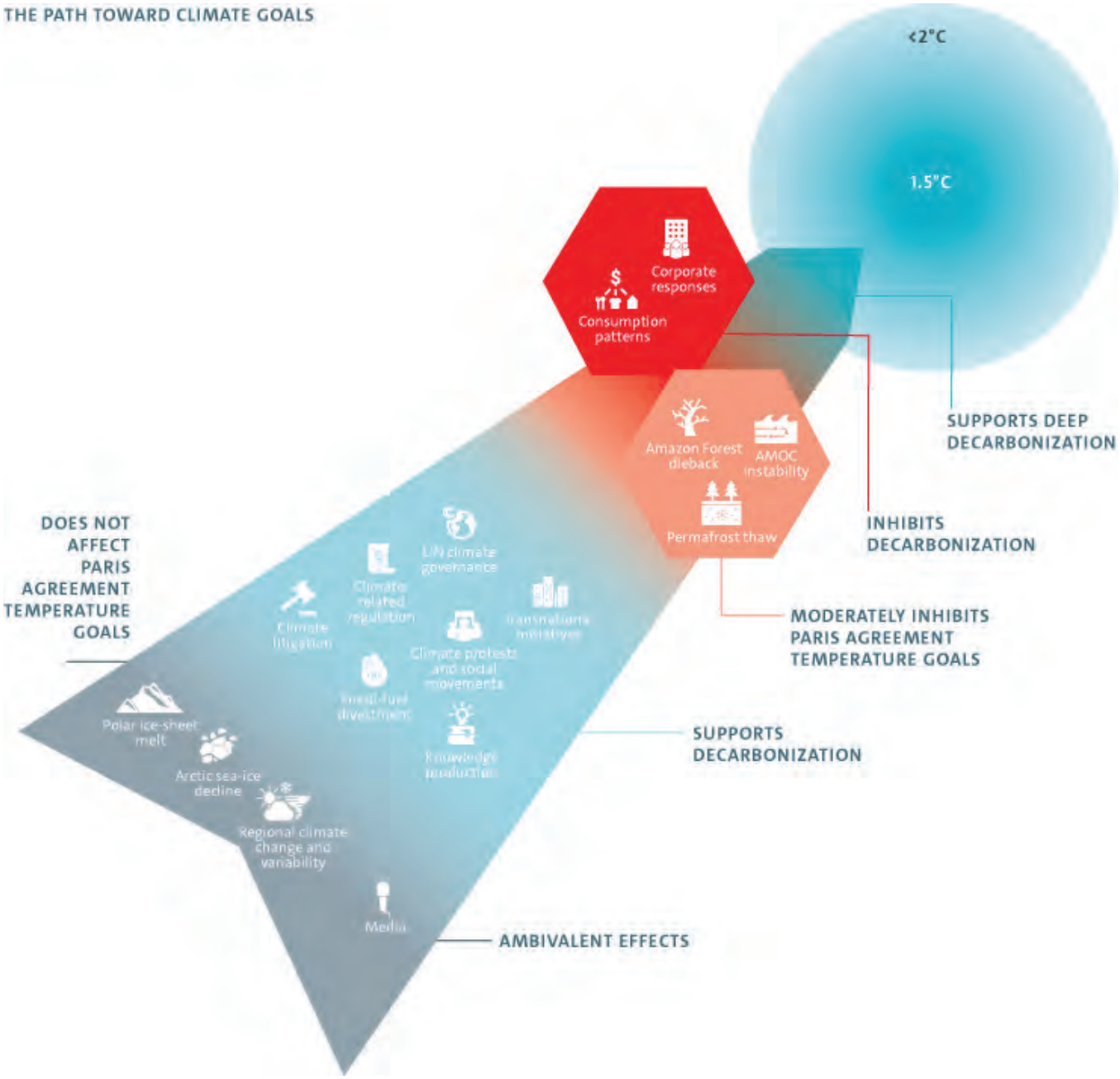


Figure 3: The path toward climate goals. The plausibility assessments indicate where social drivers and physical processes position themselves on the path toward the climate future scenario in which global climate mitigation goals are attained. Drivers and processes situated in the gray area are ambivalent with regard to reaching deep decarbonization by 2050 (social drivers), or do not affect the plausibility of attaining the Paris Agreement temperature goals (PAtg) (physical processes). Several social drivers are positioned closer to the goals as they support decarbonization (light blue area). However, the path toward climate goals is obstructed by physical processes which moderately inhibit the plausibility of attaining the Paris Agreement temperature goals (light red hexagon), and even more by social drivers which inhibit decarbonization (red hexagon). Currently, no social driver positions itself on the path of supporting deep decarbonization. More information can be found in Tables 1 and 2 and in the assessments in Chapter 6.

reduced deforestation in the Amazon Forest and the implementation of a more ambitious climate policy agenda (Section 6.1.1)—an important step toward emissions reduction and biodiversity conservation.

Climate risks, public discourses, and contestation: Public discourses often focus on climate-change-related risks, although media attention to the topic is volatile. We observe both alarmist messages (e.g., on risks related to an AMOC slowdown) and urgency narratives (e.g., on weather extremes) by activists' discourses and messaging and media reporting (Sections 6.1.9, 6.1.4, and 6.2.4). These messages and narratives intensify public discourses on climate change, but have ambivalent effects on the plausibility of reaching deep decarbonization or attaining the Paris Agreement temperature goals. These messages seem to be more persuasive the closer they are to individuals' lives (Section 6.1.9), and partial successes have been observed. For example, as a reaction to failed multilateral and state responses to provide environmental public goods, several transnational initiatives have evolved, such as contestations of climate-skeptical governments in the US and Brazil by local authorities and businesses (Section 6.1.2). Contestations around government inaction, political-agenda framing by social movements, pro-climate litigation processes, and many other climate actions are supported by and support, inter alia, scientific, institutional, local, and Indigenous knowledge (Sections 6.1.2, 6.1.4, 6.1.5, and 6.1.10).

Regional climate variation, social inequality, and climate justice: Increased awareness of and public support for counteracting human-induced climate change and related policies help establish climate justice as a fundamental norm of global climate governance (Sections 6.1.4 and 6.1.5). Integrating diverse ways of knowing and justice claims spur drivers' dynamics toward deep decarbonization, while neglecting them might constrain societal transformation. Vulnerability, migration, and displacement, such as in Small Island Developing States threatened by sea-level rise (Section 6.2.3), appear not necessarily as a direct cause of climate change, but filtered through existing inequalities and also exacerbating them. For example, regions that are expected to witness relatively large changes in extremes correspond to those countries that are characterized by low CO_2 emissions, low income, and high vulnerability (Section 6.2.6). Furthermore, inequalities in the production of knowledge, in which diverse ways of knowing climate change are excluded in central packaging processes, have constraining effects on reaching deep decarbonization (Section 6.1.10). For instance, some Indigenous and local ways of knowing can provide examples of sustainability and can be valuable resources for policy and regional dynamics, such as the protection of permafrost soils via reindeer management (Section 6.2.1).

3.4

Implications of failing to attain global climate mitigation goals

In the plausible case of failing to limit the global temperature increase to 1.5°C (Section 3.1), the observed changes in the physical world will continue and intensify. At warming greater than 2°C above pre-industrial levels, additional carbon will be released by thawing permafrost, while less carbon will be taken up by the Amazon Forest. In a warmer climate, some extreme weather events will intensify, and hemispheric co-occurrence (e.g., heat waves, droughts, and floods) will become more frequent. These will have both severe socioeconomic consequences (Section 6.2.6) and devastating impacts on ecosystems, such as in Amazonia. Here, extreme weather events and a high fire regime will become the new norm, with a potential shift toward savanna-like vegetation. Continued warming is expected to prolong ice-free periods in the Arctic Ocean, raising the prospect of an ice-free Arctic Ocean all year round. Furthermore, the melting of polar ice sheets will continue, with consequent global sea-level rise. Different to the other physical processes assessed, there is insufficient evidence for assessing the consequences of continued warming for the AMOC, since its weakening throughout the 21st century is expected to be independent of the emissions scenario.

Following these projections in the case of continued global warming, the physical plausibility assessments also address the plausibility of triggering drastic or abrupt changes in process dynamics in the 21st century. This plausibility increases as global-warming levels increase. In a number of instances, clear statements about this plausibility can be made. For example, modeling and observational evidence suggests a linear decline of Arctic summer sea ice under continued warming; hence, abrupt changes in the 21st century are not plausible. It is similarly clear that, if certain temperature levels are crossed, the basic process dynamics of polar ice sheets will very likely change drastically in the future. However, when assessing the plausibility of drastic changes in the 21st century, uncertainties can play a crucial role—for example, model descriptions or understandings of processes may hinder a faithful projection of future evolution of drastic and abrupt changes. This is the case with permafrost thaw, for which drastic changes in permafrost carbon storage under continued warming in the 21st century cannot be ruled out. By contrast, following the IPCC's sixth assessment report, we can state with medium confidence that an abrupt collapse of the AMOC within the 21st century is not plausible.

The assessments dealing with polar ice sheets and the Amazon Forest show that we have to distinguish between regional or local and large-scale thresholds for drastic changes (here, in the sense of tipping). Indeed, tipping points result from the interaction of a multitude of factors (Section 6.2.5), since important thresholds for specific processes can depend on local conditions, drivers, and cause-effect relationships. We see that local thresholds are more likely to be crossed than large-scale thresholds, and increased global warming will trigger more and more local instabilities, causing a sharp rise in the plausibility of abrupt local changes. This is the case for polar ice sheets, where evidence shows that regional instabilities (tipping points) have possibly been triggered already and will be triggered in the future, causing a sharp rise in sea-level rise. In the case of the Amazon Forest, since ecosystem resilience strongly depends on local conditions, a uniform large-scale dieback of the Amazon Forest solely driven by climate change (e.g., by a decrease in precipitation) during the 21st century is not plausible; rather, regional dieback is plausible.

However, the greatest changes are expected to come from anthropogenic deforestation and forest degradation. In this case, uncertainties concern future social development. The combined forces of deforestation and climate change make Amazon Forest dieback plausible, unless policy and regulatory measures as well as financial incentives are halted. Future social developments that facilitate decarbonization help contextualize projections of future physical processes. For example, even a worst-case increase of CH_4 emissions from permafrost thaw will be small compared to the possible reduction of anthropogenic CH_4 emissions through global mitigation measures. In addition to mitigation, adaptation measures are tightly linked to future plausible drastic changes in physical processes' dynamics. Indeed, the occurrence of regional low-likelihood but potentially high-impact outcomes in the 21st century is plausible. Unprecedented extreme compound events are expected to occur with higher warming, potentially leading to dramatic socioeconomic changes.

To summarize, the assessments reveal three points: First, drastic or abrupt changes in the 21st century in the polar ice sheet and regional climate are plausible if the Paris Agreement temperature goals are exceeded but not plausible for the Arctic sea ice or the AMOC. Second, human action is a fundamental condition that can either enable or

constrain the plausibility of large-scale dieback of the Amazon Forest. Third, uncertainties about the behavior of permafrost carbon preclude us from assessing the plausibility of drastic changes within the 21st century. That said, it can be excluded that permafrost thaw can lead to a runaway climate warming.

3.5

Conditions and resources for societal transformation

In this final section, we address a series of conditions and resources for societal transformation required for attaining the Paris Agreement temperature goals to become *plausible* (Table 1). Even if the results of our driver assessments suggest that societal transformation cannot be achieved easily, human agency still has a large potential to shape the way climate futures will evolve. This implies that human action is a fundamental condition to support or inhibit the pathways toward limiting the global temperature increase to below 2°C (for a discussion on the implications of our findings to climate futures, see Chapter 5).

For the social drivers to support deep decarbonization by 2050 and therefore the attainment of the Paris Agreement temperature goals, a series of changes in their dynamics are required. An end of Russia's invasion of Ukraine and reducing the tensions between US and China would be fundamental conditions for UN climate governance and multilateral cooperation on climate change. The impact of Russia's aggression on energy security may represent an opportunity for deep decarbonization if governments and high emitting corporations are pushed to divest and reduce their dependence on fossil fuels on a large scale. In light of this, broad societal support for climate action and pressure on governments to close implementation gaps—through pro-climate litigation processes, transnational initiatives, climate protests and social movements—are crucial for deep decarbonization by 2050 to become plausible. Implementation gaps with regard to climate mitigation can also be addressed through the adoption of science-based decarbonization targets by a wide range of companies as well as through broader participation of members from high-emitting sectors and countries in transnational initiatives and improved non-state actors' accountability regarding their net-zero commitments. In this context, the establishment of common and mandatory accounting norms and boundaries at organizational level, and of independent target validation and third-party auditing of greenhouse gas emissions is expected to help address both knowledge gaps and implementation gaps in climate mitigation.

Furthermore, strengthening the increasing body of (supra)national pro-climate legislation and the enactment of climate-related regulation focused on just transitions are key changes needed for the social drivers' dynamics to support deep decarbonization. The same is true of effective regulatory measures on fringe media. The structural transformations necessary for deep decarbonization would require increased implementation of climate-related law, regulation, and policies that address persistent structural challenges such as extreme social inequalities, carbon-intensive consumption patterns, and fossil-fuel lock-ins. These include energy transitions (e.g., replacing fossil fuels with renewable energy), the implementation of climate-friendly infrastructure (e.g., to facilitate transport-mode switching), as well as changes in production processes so as to increase the lifetime of goods and services and to reduce waste in consumption. Such transformations are plausible in a context of increased pressure for investors to divest in fossil fuels, integration of diverse ways of knowing into decision-making processes, and synergies between climate-related regulation and knowledge production on plausible post-growth climate mitigation scenarios. Addressing uncertainties in climate modeling and significant advances in attribution science are also key to support the dynamics of social drivers, such as climate litigation and climate protests and social movements, toward deep decarbonization. Last but not least, more engagement and influence of individuals and organizations with strong and independent climate science journalism is necessary to support societal mobilization for climate action and change toward deep decarbonization.

Densification of the global opportunity structure for climate action

A dense global opportunity structure that provides a variety of resources for climate action is a

necessary condition to increase the momentum or change the direction of social drivers toward deep decarbonization. In the present Outlook, the social plausibility assessments show that global opportunities for climate action multiply, gain visibility, and materialize at least incrementally. In relation to the previous edition, we observe a quantitative increase of climate-related activities, such as more climate-related regulations, protests, net-zero pledges, and transnational initiatives within UN climate governance and beyond (Sections 6.1.1, 6.1.2, 6.1.3, and 6.1.4). However, these activities do not necessarily translate into a reduction of persistent ambition, implementation, and knowledge gaps. We observe only limited evidence in terms of qualitative shifts in the global opportunity structure for climate action. These relate to incremental changes in soft and hard law or to voluntary and binding schemes of climate governance (Sections 6.1.1 and 6.1.5). Negotiations at the COP26 in Glasgow, UK, have not managed to address implementation gaps and required steps to phase out fossil fuels. This is by and large also true for COP27 in Sharm el-Sheikh, Egypt, which took place after our assessment of UN climate governance was finalized. Nationally Determined Contributions (NDCs), transnational initiatives, fossil-fuel divestment, and corporate responses remain largely voluntary, despite the pressure from climate litigation and social movements to render these into legal provisions or policies (Sections 6.1.2, 6.1.6, and 6.1.7). In fact, the densification of the global opportunity structure in terms of quantitative increases still requires qualitative shifts in the resources for climate action, such as new forms of activism, new policy instruments, and hardening of soft law (Sections 6.1.3, 6.1.4, and 6.1.5). The same is true of low-carbon consumption patterns (Section 6.1.8) and increased integration of diverse actors and ways of knowing into knowledge production, decision-making, and climate governance processes (Section 6.1.10). In this regard, Indigenous Peoples play a crucial role in bringing these issues to the fore along with climate protests and social movements and in helping preserve existing natural forests, which can make a greater contribution in terms of natural sinks toward carbon neutrality than afforestation (Sections 6.1.4, 6.1.10, and 6.2.5).

Authors:
Anna Pagnone, Eduardo Gonçalves Gresse, Andrés López-Rivera, Jan Wilkens, Anita Engels, Jochem Marotzke

Table 1
Stefan C. Aykut, Jill Bähring, Alexander Bassen, Michael Brüggemann, Timo Busch, Solange Commelin, Emilie d'Amico, Anita Engels, Thomas Frisch, Anna Fünfgeld, Eduardo Gonçalves Gresse, Lars Guenther, Charlotte Huch, Johannes Jarke-Neuert, Matthew Johnson, Katharina Kleinen-von Königslöw, Andrés López-Rivera, Cleovi Mosuela, Franziska Müller, Manuel Neumann, Christopher N. Pavenstädt, Grischa Perino, Delf Rothe, Theresa Rötzel, Jürgen Scheffran, Felix Schenuit, Erika Soans, Svenja Struve, Martin Wickel, Antje Wiener, Jan Wilkens, Cathrin Zengerling

Table 2
Christian Beer, Victor Brovkin, Christiane Fröhlich, Thomas Kleinen, Christian Knoblauch, Michael Köhl, Lars Kutzbach, Chao Li, Andrés López-Rivera, Jochem Marotzke, Martina Neuburger, Dirk Notz, Anna Pagnone, Simone Rödder, Jana Sillmann, Philipp de Vrese

TABLE 1

Summary of social plausibility assessments

Social drivers	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?	
Supports deep decarbonization by 2050 Supports decarbonization, insufficient for deep decarbonization by 2050 Ambivalent with regard to deep decarbonization by 2050 Inhibits decarbonization		enabling conditions constraining conditions effect uncertain	
6.1.1 UN climate governance 	**Supports decarbonization, but not sufficient for deep decarbonization by 2050.** COP26 relaunched UN climate governance. It facilitated new sectoral initiatives, net-zero pledges, and a call to "phasing down" coal and "phasing out" fossil-fuel subsidies. If implemented, new pledges and initiatives could limit warming to 2.1°C and below in the most optimistic scenarios. But initiatives are non-binding and ambition of NDCs insufficient. The "trust gap" in climate finance delivery constitutes a major obstacle for UNCG's ability to facilitate low-carbon development in the Global South.	Russia's invasion of Ukraine: opportunities for quicker decarbonization, but risks of "securitizing" climate policy and locking in new fossil-fuel dependencies. COVID-19: recovery programs in most countries did not end fossil-fuel lock-in. Climate protests regaining momentum through COP26 after many COVID-19-related restrictions were lifted. Pro-climate legislation in the USA, EU; climate-friendly governments e.g., in Australia, Brazil.	
6.1.2 Transnational initiatives 	**Supports decarbonization, but not sufficient for deep decarbonization by 2050.** Transnational coordination of cities, regions, businesses, and investors can help reduce global emissions. They contribute to climate governance through advocacy, policy monitoring, best practice exchange, development of voluntary market standards (e.g., ecolabels, emission trading schemes, reporting standards, disclosure platforms). Their effectiveness depends on a high sustainability standard, enforcement mechanisms, and a wide uptake, which is not always the case.	Hightened visibility helped to attract new initiatives, increase ambition, launch new campaigns. While they mostly rely on a market logic, transnational initiatives have struggled to structure viable business cases for sustainability markets in a context of low and fragmented carbon pricing. There is a lack of key institutional arrangements (e.g., ambitious target design, monitoring and reporting obligations, third party auditing, enforcement procedures) and national regulatory frameworks.	
6.1.3 Climate-related regulation 	**Supports decarbonization, but not sufficient for deep decarbonization by 2050.** In addition to a residual ambition gap, there is a substantial implementation gap in all major carbon-emitting jurisdictions.	There are promising reforms under way, especially at the EU level. Current reforms face fierce opposition due to structural conflicts and the recent surge in energy prices. Bans of energy imports from Russia are amplifying the problem. Several measures to relieve consumers and industry from rising energy bills effectively take the form of fossil-fuel subsidies.	
6.1.4 Climate protests and social movements 	**Supports decarbonization, but not sufficient for deep decarbonization by 2050.** Climate protests and social movements have become key players in the climate-related political process. Short-term direct effects of the driver appear to be limited; long-term and often indirect effects such as shifts in broader public perceptions suggest a positive effect toward deep decarbonization, supported by a growing importance of the climate justice frame.	General and ongoing public interest in and focus on climate policies. Russia's invasion of Ukraine, the ongoing COVID-19 pandemic, and its consequences. While it is not yet possible to fully assess the scale of impacts, the ability to mobilize and shape public discourse to support decarbonization is challenged in light of growing concerns over energy security.	

	In relation to the 2021 Outlook assessment, 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) would a change in direction toward deep decarbonization be expected?	Does this driver provide global resources that are visible and accessible to other social actors or drivers, and how are these resources changing or showing signs of changing?
	➤ or ➤ signs of change in direction toward or away from deep decarbonization ⛔ No signs of change in the directon of the driver		
	➤ Glasgow COP was an important milestone in the post-Paris process, but NDC ambition levels and implementation efforts are still far from Paris Agreement goals.	A major change in direction can be expected as a result of new geopolitical developments: (i) new international cooperation following an end of Russia's invasion of Ukraine, or (ii) a breakdown of UN multilateralism as a consequence of rising US-China tensions.	This driver provides an arena for public performances, showcases best practices and instruments of soft coordination, orchestrates transnational climate governance. It institutes cycles of country submissions and reporting mechanisms that facilitate and synchronize climate-related regulations. It constitutes media opportunities for climate-related performances, agenda setting, and framings for climate protests.
	➤ The past three years saw substantial increase in the number of transnational initiatives and progressive upgrading of ambitions to align with the 1.5°C temperature goal. Since 2020, the Race to Zero campaign has mobilized thousands of non-state and subnational actors operating in multiple sectors for the adoption of net-zero pledges at the entity level. Transnational initiatives facilite a strategic shift toward the implementation of the net-zero pledge via standard setting and advisory activities.	Transnational initiatives will support deep decarbonization, provided that they attract new members from high emitting sectors and countries in the future. They can also improve transparency on greenhouse gas emissions if they diffuse ambitious reporting standards and solve data gaps to establish credible baselines. Broader participation in decision-making will be key to establish stringent environmental criteria while protecting human rights, nature, and equity. Finally, effective accountability will not happen without favorable regulations and policy incentives.	Transnational initiatives support UN climate governance by advocating more ambitious and participative NDCs, creating supportive global narratives, translating international climate norms for non-state and subnational actors. They formulate policy recommendations and design standards for climate-related regulation and implementation, e.g. policy monitoring. They guide corporate responses through capacity building and best practice sharing, develop standards, offset certifications and ecolabels for the development of sustainability markets. They produce and provide key information, knowledge, and expertise in support of divestment strategies, sustainable consumption patterns, and social movements. They frame political agendas, and influence public opinion.
	➤ Given the current trends and conditions, the signs are that a significant implementation gap will persist for several years to come.	Closing the implementation gap under the voluntary architecture of the Paris Agreement requires voters and interest groups to place continuous pressure on governments not only to set and stick to abatement pledges, but rather to put effective climate policy instruments in place. The climate litigation driver might play an important role in keeping governments on track.	Regulatory innovations and stringent implementation can be key material resources for other social drivers if they create enabling conditions for climate litigation and fossil-fuel divestment. The EU Green Deal and the Fit for 55 package can provide scripts as potential role models for decarbonization. If both ambition and implementation gaps were overcome in major economies, this would provide symbolic and material resources for the global opportunity structure.
	➤ Social movements' internal struggles and tensions regarding mobilization, repertoires, and justice issues as well as implications of the COVID-19 pandemic and Russia's invasion of Ukraine constrain the driver in the short term. Nevertheless, social movements and climate protests support deep decarbonization in the long term by raising awareness within society and among policymakers.	Addressing the internal and external challenges and constraints could further support and accelerate change toward deep decarbonization. At the same time, it remains an open question whether the process of contestation over strategy and scope of desired changes within movement factions will result in stronger political alliances and broader support.	Climate protests and social movements occupy a central position in many climate debates, and provide ideas, norms, and visions. These can trigger reinterpretations of meaning for societal discourses and for individual lifestyle choices, e.g., the recent trend toward climate justice reframes climate change and associated policy preferences. The driver generates media attention, has an influence on public agendas, and creates public pressure. This provides incentives to divest from fossil fuels. Social movements have often developed into NGOs, which are consulted for specialized knowledge. The driver further provides repertoires and spaces for sustainable practices.

Social drivers	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?
Supports deep decarbonization by 2050 Supports decarbonization, insufficient for deep decarbonization by 2050 Ambivalent with regard to deep decarbonization by 2050 Inhibits decarbonization		enabling conditions constraining conditions effect uncertain
6.1.5 Climate litigation 	**Supports decarbonization, but not sufficient for deep decarbonization by 2050.** Climate litigation supports decarbonization in close interaction with climate-related regulation, knowledge production, climate protests and social movements, fossil-fuel divestment, corporate responses, and media. It is plausible that climate litigation will increase further, target more companies of the fossil-fuel industry and beyond, and spread geographically—with the exception of the US where recent developments in the US Supreme Court might have a deterring effect.	We observe a strengthening in "rules of engagement" for climate action (access to justice, fundamental legal norms, scientific evidence, social institutional environments). Legal, scientific, and sociopolitical enabling conditions of climate litigation were also mostly strengthened. With regard to the US, we found negative developments in the "rules of engagement" and legal enabling conditions (conservative majority in the US Supreme Court and its negative ruling on US EPA's lack of authority to regulate greenhouse gas emissions).
6.1.6 Corporate responses 	**Inhibits decarbonization.** Current corporate responses undermine the social dynamics and global efforts toward deep decarbonization. Despite recent trends of net-zero pledges and science-based targets, the majority of companies are still not responding adequately to support decarbonization.	Market-based developments tie closely with investor relations and consumption patterns, which often undervalue decarbonization strategies. Non-market developments include many transnational initiatives supportive of corporate decarbonization, among them the Science Based Targets initiative (SBTi) and the Task Force on Climate-Related Financial Disclosures.
6.1.7 Fossil-fuel divestment 	**Supports decarbonization, but not sufficient for deep decarbonization by 2050.** Fossil-fuel divestments are growing in number and volume, but these are not sufficient to prevent investments in fossil-fuel engagements from being profitable or at least politically necessary. Governments on average continue to plan for massive investments in coal, oil, and natural gas.	There is a growing market for green or fossil-free financial products. Long-term expectations are slowly building up (but not yet widespread) that fossil fuels will eventually become "unburnable" and turn into stranded assets. The profitability of fossil-fuel engagements is expected to remain high, at least in the short term. Subsidies for fossil fuels are continuously granted in many countries.
6.1.8 Consumption patterns 	**Inhibits decarbonization.** Current worldwide consumption patterns substantially undermine the social dynamics and the global efforts toward deep decarbonization. The limited effects of changes toward low-carbon consumption patterns are expected to be further largely absorbed by the continued growth in the demand and production of (new) carbon-intensive goods and services.	Implementation of climate-friendly infrastructure, increased energy efficiency, replacement of fossil fuels by renewable energy supply, some behavioral changes, increasing lifetime of products, tackling social inequalities. Effects of enabling conditions are nullified by several constraining conditions, e.g., hegemony of growth- and fossil-fuel-based political and economic systems, unequal distribution of wealth, goods, and services, along with the institutionalization of massive (and uneven) high-carbon consumption patterns.
6.1.9 Media 	**Both supports and inhibits deep decarbonization (ambivalent).** Journalistic attention to climate change reveals volatile behavior. Although journalistic reporting has become more interpretative and evidence-based, a focus on conflict can still allow for climate denial to enter media coverage. The journalistic framing of the topic is only to some degree aligned to what has been deemed a successful framing in media effect studies.	Trends toward transformative journalism and newly established formats and websites. Conservative political leaning of some media organizations, the challenges (science) journalism faces, competition by sources of information not constraint by journalistic norms and values. Social media platforms fulfill different roles in the climate change debate and many fringe media seem to promote an anti-science agenda with regard to climate change.
6.1.10 Knowledge production 	**Supports decarbonization, but not sufficient for deep decarbonization by 2050.** An increase in packaged knowledge resources supports decarbonization and adaptation. Some global sites of knowledge production provide resources for societal agency toward decarbonization through policy-oriented assessments and increased earth observation capacities. Deep decarbonization requires a greater integration of diverse ways of knowing to produce socially robust knowledge.	Packaged knowledge constitutes an enabling condition in political processes by providing global climate data and research that informs decision-making in envisioning and enacting decarbonization pathways. Packaged knowledge becomes a constraining condition when it fails to integrate contextual knowledge, which is required for socially just transitions.

	In relation to the 2021 Outlook assessment, 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) would a change in direction toward deep decarbonization be expected?	Does this driver provide global resources that are visible and accessible to other social actors or drivers, and how are these resources changing or showing signs of changing?
	➤ or ➤ signs of change in direction toward or away from deep decarbonization ⛔ No signs of change in the directon of the driver		
	➤ We do not observe signs that the direction of the driver is changing on a large scale. Russia's invasion of Ukraine yields new reasons for a fast energy transition that can be used in climate litigation, but the conservative majority in the US Supreme Court and its recent decision on West Virginia v. EPA is likely to slow down climate litigation in the US but not elsewhere.	Accelerating enabling conditions include broader access to courts, new landmark rulings in favor of climate protection (e.g., company liability, change in burden of proof), an enhanced push toward more hybrid movements including contestation of climate politics with the view of taking the adversaries to court, and significant advances in attribution science.	Key global resources: Legal precedents (case law), network capacities (cross-scale litigation networks, enabling circulation of practices, people, frames, and knowledge), expert knowledge (e.g., research conducted to establish causality and attribute emissions), climate-related frames and narratives (e.g., climate justice, corporate responsibility) and agenda-setting (via political discourse and media coverage). We observe a shift from mere visibility toward materiality of climate litigation-related repertoires in the global opportunity structure.
	⛔ Two parallel transnational initiatives may indicate that this driver can potentially change in the future: the Science Based Target initiative (SBTi) and the Race to Zero Campaign of the UNFCC. While only a small fraction of all companies is adopting such measures currently, these have great potential to gain traction among the heaviest emitters in all industries.	As corporations conduct business on global levels, two other drivers will support a change of corporate responses toward deep decarbonization: transnational initiatives and consumption patterns. Transnational initiatives as intermediaries between the public and private sectors can strengthen climate-related regulation and pressure from investors and other stakeholders. If consumption patterns move toward deep decarbonization, corporations will follow because of their profit-seeking motivation.	Via reporting and disclosure, corporate responses provide knowledge that can support societal agency in other drivers, such as information for investment or divestment decisions, or reference points for climate litigation and for climate protests and social movements. If net-zero targets are backed by strong corporate mitigation efforts, this would provide climate-neutral goods and services to consumers and could thus change consumption patterns.
	➤ We register increased attention among investors and attempts to create transparency and engage in rule setting to push for divestment.	Russia's invasion of Ukraine could push governments toward reducing their dependence on fossil fuels. Governments would need to realign their fossil-fuel plans with their climate pledges and reduction targets under the Paris Agreement. We also see a chance that climate litigation is used to push governments in this direction. Some large-scale initiatives tackling fossil path dependency and stranded assets are being introduced.	Divestment decisions serve as both a political and a financial signal to other actors. If divestment grows, it will change market conditions for corporations and thus trigger corporate responses toward decarbonization. At the moment this driver is more dependent on resources coming from other drivers (e.g., climate-related regulations, UN climate governance, transnational initiatives, social protests, and climate movements) than vice versa.
	➤ The growing consumption of energy, transport, food, and garments worldwide, and especially among affluent consumers, continues to drive an increase in global emissions, while no enforcement mechanisms requiring low-carbon consumption standards have been observed.	The implementation of ambitious climate-related regulations and a limitation of carbon-intensive luxury consumption might significantly change the ongoing dynamics of this social driver. Knowledge production on the constraining conditions for sustainable production and consumption systems and exploring post-growth climate mitigation scenarios can also shift consumption patterns toward decarbonization, especially if reinforced by fossil-fuel divestment and ambitious corporate responses to climate change.	This driver has an important impact on global emissions and on the dynamics of other social drivers of decarbonization, such as corporate responses and fossil-fuel divestment. The ways in which worldwide consumption patterns evolve provide these and other social drivers such as knowledge production, climate litigation, and climate-related regulation with important insights into what enables or constrains significant shifts in consumers' habits.
	⛔ The direction of this driver is in constant flux. This direction is dependent on individual patterns of information use, the role journalism plays in society, and the degree to which social media and fringe media are regulated. Pressing issues such as the COVID-19 pandemic or Russia's invasion of Ukraine in 2022 also limit media attention to climate change.	High journalistic attention, an empowering framing, the engagement of individuals and organizations, strong and independent (science) journalism, and effective countermeasures/regulations for social media and fringe media would ensure greater support for deep decarbonization.	This driver provides attention and visibility to all other drivers, and establishes new framings—this is especially true for journalism because of its broader reach. There may be more destabilizing effects of social and fringe media that need to be considered. Furthermore, the driver supports diverse ways of knowing: there are increasingly more actors, voices, and frames represented in diverse media (outlets). These media (e.g., journalistic, social, and fringe) are also interconnected in such a way that they affect each other.
	⛔ In our updated assessment, we do not observe signs that the direction of the driver is changing. The ongoing COVID-19 pandemic and Russia's invasion of Ukraine may shift global attention to other issues. Knowledge production with regard to climate change remains a central dynamic.	Enabling conditions include a more systematic and profound approach to account for diverse ways of knowing and justice, for example in energy transitions, and a broader consideration of social dynamics. The growing tendency to focus on technological fixes excludes required social engagements with conditions for deep decarbonization.	The driver particularly shapes and interacts with media, climate protests and social movements, climate litigation, and UN climate governance. While technological developments can provide additional knowledge resources and thus positively shape the pathways toward deep decarbonization in other drivers, they can also create new barriers and limit the accessibility of knowledge.

TABLE 2

Summary of physical plausibility assessments

Physical processes	How did the physical process evolve in the past?	What would the continuation of recent dynamics under increased global warming mean for the prospect of attaining the Paris Agreement temperature goals (PAtg)?	
		supports the attainment of the PAtg does not affect the attainment of the PAtg moderately inhibits the attainment of the PAtg inhibits the attainment of the PAtg	
6.2.1 Permafrost thaw 	Significant permafrost warming was observed over the past 30–50 years. Thickening of the soil active layer and an increase of abrupt permafrost thaw phenomena, such as thermo-erosion and thermokarst, were detected. There is limited evidence of trends in annual CO_2 and CH_4 emissions.	About one year of today's anthropogenic emissions could be released by permafrost thaw between now and 2050. Thus, permafrost thaw moderately inhibits the plausibility of attaining the Paris Agreement temperature goals.	
6.2.2 Arctic sea-ice decline 	A rapid decline as a linear response to changes in the external forcing was observed. No sign of a tipping point is seen.	The loss of Arctic sea ice in the summer has little potential to directly affect the prospects of achieving the Paris Agreement temperature goals, partly because its impact on the temperature of the surrounding permafrost regions is limited.	
6.2.3 Polar ice-sheet melt 	Substantial ice-mass loss at an accelerating rate was detected. The melting of polar ice sheets is expected to be the dominant source of global-mean sea-level rise over the coming decades.	The melting of polar ice sheets barely has a direct impact on the global-mean temperature.	
6.2.4 Atlantic Meridional Overturning Circulation (AMOC) instability 	Global warming is expected to weaken the AMOC, but measurements so far have been inconclusive regarding whether such weakening has already occurred.	The expected slowdown and even more a potential collapse of the AMOC would lower the prospects of reaching the Paris Agreement temperature goals, because the slowing down AMOC would remove less heat and CO_2 from the atmosphere.	
6.2.5 Amazon Forest dieback 	Changes in precipitation, more frequent and intense weather extremes, and prolonged fire seasons were observed. The Amazon Forest undergoes extensive deforestation and forest degradation. The Amazon Forest is losing resilience. The Amazon carbon sink is declining.	Though a decline in carbon sink is observed, models still show uncertainties with respect to tropical carbon pool sensitivity to climate change. Extrapolating from the current trend in Amazonian deforestation until 2050, we predict less than 7 GtC of additional accumulated emissions until 2050. Thus, deforestation of the Amazon Forest can moderately inhibit the plausibility of attaining the Paris Agreement temperature goals.	
6.2.6 Regional climate change and variability 	Changes in the polar vortex, storm tracks, jet stream, and planetary waves, which can affect the frequency, intensity, duration, seasonality, and spatial extent of weather extremes like cold spells, heat waves, and floods, were observed.	Changes in mean climate and extremes will be either amplified or attenuated by internal variability, which will therefore co-determine the frequency and intensity of extreme events on a regional scale.	

	What are the consequences of failing to attain the Paris Agreement temperature goals, and what would be the consequences for this physical process of exceeding given global warming levels?	In which way is this physical process connected to other physical and social processes?	Is it plausible that drastic or abrupt changes in the basic dynamics of this process are triggered within the 21st century?
		interconnections between physical processes **interconnections between physical and social processes**	**no plausible drastic or abrupt change** **plausible drastic or abrupt change** **uncertain about the plausibility of drastic or abrupt change**
	Additional carbon release proportional to the warming is expected. Permafrost carbon is considered a tipping element with the potential for abrupt climate change under continued warming.	We see additional effects on regional and global climate change through changes of the hydrological cycle and land-atmosphere interactions. Permafrost thaw has serious impacts on local ecosystems, wildlife, and human infrastructure and communities, as well as adverse effects on reindeer herding. Permafrost thaw threatens the symbolic representations, material practices, and emotional ties that local communities have developed toward their land.	Due to existing gaps in understanding and modeling of abrupt thaw processes, plant-soil interactions, and disturbances such as fires, we cannot rule out that drastic changes in permafrost carbon storage might occur in the 21st century. Even a worst-case increase of CH_4 emissions from terrestrial permafrost landscapes due to Arctic climate change will be considerably smaller than plausible reductions of global anthropogenic CH_4 emissions by mitigation measures.
	The ice-free period of the Arctic will become longer, raising prospects of an Arctic Ocean that is ice-free all year round, but it is still unclear at which level of global warming this might occur, because climate models underestimate the sensitivity of the Arctic sea-ice cover to global warming.	There is low confidence that Arctic sea-ice loss plays a substantial role in the modification of weather patterns in other regions of the planet. Sea-ice decline has limited impact on additional thaw of land permafrost. Sea-ice decline is a threat to animals and peoples in the Arctic.	All modeling and observational evidence suggests a largely linear loss of Arctic summer sea ice in response to ongoing warming. Hence, abrupt changes in Arctic sea ice in the 21st century are not plausible.
	The polar ice sheets will cross more and more regional tipping points, which will rapidly and strongly increase the long-term committed global mean sea-level rise.	The melting of polar ice sheets impacts the global ocean circulation, with freshwater input from Greenland potentially increasing the heat accumulation in the Southern Ocean, causing additional ice loss. The sea-level rise caused by ice-sheet melt is a key driver for migration and displacement.	It is not only plausible but indeed very likely that the basic process dynamics will change drastically if certain temperature levels are crossed. There is some evidence that regional instabilities have possibly been triggered already. With increasing global warming, more and more of these instabilities will be triggered, causing a sharp rise in committed sea-level rise.
	While AMOC weakening over the 21st century is very likely, the rate of weakening is approximately independent of the emissions scenario (high confidence). We therefore conclude here that there is insufficient evidence for assessing plausible consequences for the AMOC, if any, if the goals of the Paris Agreement were not met.	AMOC weakening is expected to respectively increase and stabilize the ice mass loss from the Antarctic and Greenland Ice Sheets. AMOC weakening might cause changes in large-scale precipitation patterns. It is currently not possible to assess what wider societal effect the attention to the weakening might cause.	A relatively sudden collapse of the AMOC for a specific amount of freshwater forcing in the North Atlantic is possible. The IPCC AR6 expresses medium confidence that the declining AMOC will not involve an abrupt collapse within the 21st century.
	Weather extremes and a high fire regime will become the new norm in Amazonia, which could shift toward a savanna-like vegetation with devastating impacts on the ecosystems. Regional dieback is plausible. Not only climate change, but also human activities are pushing the Amazon Forest toward tipping points.	Changes in the AMOC, weather extremes, and a warmer North Atlantic could lead to a drier Amazonia in the future. It is not a single factor but the interaction of various economic, institutional, technological, cultural, and environmental factors that is responsible for deforestation. Since the end of the 19th century several Amazonian states started protecting forest and Indigenous areas. If forests are to contribute as natural sinks to achieving carbon neutrality, preserving existing natural forests can make a much greater contribution than afforestation.	Large-scale dieback of the Amazon Forest solely driven by climate change during the 21st century is not plausible. However, the greatest changes are expected to come from deforestation and forest degradation. By assessing current trajectories we conclude that a scenario of forest dieback under combined forcings of deforestation and climate change within the 21st century is plausible, unless policy and regulatory measures, as well as financial incentives, are strengthened.
	More concurrent and multiple changes in climate extremes associated with severe impacts in various sectors (e.g., hemispheric co-occurrence of extremes with severe socioeconomic consequences) are expected.	Changes in regional climate variability and extreme events have socioeconomic relevance and could affect sustainability and security through cascading impacts across sectors. This can lead to either negative or positive changes in social or environmental systems.	The occurrence of regional low-likelihood but potentially high-impact outcomes cannot be ruled out, even if the global warming falls within its very likely range for a given emissions scenario. With higher warming more extreme compound events that were unprecedented in the observational record are expected to occur, potentially leading to dramatic socioeconomic changes.