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Dealing with the 1.5 °C goal

Position paper

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ABOUT US

Encompassing 28 member institutions, the German Climate Consortium (DKK e. V.) gathers together the leading players of climate science in Germany, and reflects the growing diversity of climate science and climate impact research. Alongside natural science-based climate research, the social sciences play an increasingly important role in understanding the conditions, drivers, and concepts of social change. The interactions between climate, biodiversity, sustainability, and transformation research are a further focus of the DKK.

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Key messages

1. **The foreseeable exceedance of the global temperature goal of remaining below 1.5°C should be openly communicated and taken into account in political action.** The Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) states that the 20-year average of the global temperature increase is expected to exceed the 1.5°C limit by the early 2030s[1]. Climate adaptation strategies should be based on and prepare for currently plausible temperature scenarios. Irrespective of this, every effort must continue to be made to limit the temperature increase in accordance with the Paris Agreement.

2. **1.5°C is not a physical threshold for climate change. There is no clear-cut transition from a safe climate to dangerous climate change.** Climate change is already causing considerable and, in some cases, irreversible damage in many parts of the world. In many places, the change in the local average temperature deviates significantly upwards and downwards from the global average.

3. **With every further increment of increase in global warming, changes in weather extremes will continue to increase.** In its Special Report on Global Warming of 1.5°C, the IPCC highlights differences in the expected climate impacts between 1.5°C and 2°C [15]. It states that there will be considerably more damage due to climate change at 2°C than at 1.5°C. The IPCC's Sixth Assessment Report shows that for every half degree Celsius increase in temperature, there will be discernibly more heatwaves, heavy rainfalls and flooding events[2].

4. **The Paris Agreement is binding under international law and therefore cannot be abandoned**. t states the goal of limiting global warming to well below 2°C and specifies this with reference to 1.5°C [3]. Article 2 states that the "threat of climate change" should be reduced by "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, recognizing that this would significantly reduce the risks and impacts of climate change". In Article 4, the Paris Agreement specifies the goal of greenhouse gas neutrality[2] and sets a time horizon for this. The article states that global greenhouse gas emissions should peak “as soon as possible […] so as to achieve a balance between anthropogenic emissions by sources and removals by sinks […] in the second half of this century”. The Paris Agreement adopted by 195 countries and the EU thus politically defines what is considered dangerous climate change and what is to be avoided through appropriate political measures.

5. **The Paris Agreement does not set a specific time horizon for the temperature goal.** However, the exact wording "*holding* the increase […] to well below 2°C" (Paris Agreement, Art. 2, emphasis added) can be interpreted as an indication that the climatically averaged temperature increase should be kept well below 2°C permanently and at all times. Nevertheless, the concept of "overshoot" – that is, temporarily exceeding the temperature threshold of 1.5°C – has emerged in the climate change discourse. However, even if the temperature goal of 1.5°C was to be exceeded only temporarily, this would increase the risk of irreversible damage, such as coral die-off, glacier melting, loss of biodiversity, or die-back of the Amazonian rainforest [18, 19].

1 See Lee, Marotzke et al., chapter 4, in [1]
2 See B2.2 in [2]

6. **Social drivers, particularly consumer behaviour and corporate strategies, counteract compliance with the 1.5°C goal.** The social sciences provide relevant evidence on this, as well as on policy options to change course. So far, the political decisions taken are insufficient to achieve the climate policy goals, especially the goal of deep decarbonization [4]. Above all, growing social inequality in many societies around the world stands in the way of decarbonization by 2050. Nevertheless, there are developments that promote the achievement of the 1.5°C goal and which should therefore be highlighted more clearly. These include the fact that globally, almost twice as much is currently being invested in renewable energies as in fossil energy production, and that the cost of solar energy has fallen by around 90 percent in the last 20 years [5, 6].

FAQs

1 How is compliance with the 1.5°C goal measured?

2 Is the 1.5°C goal still achievable?

3 When will the 1.5°C goal be exceeded according to current scientific knowledge?

4 How should a temporary overshoot of the 1.5°C goal be assessed?

5 What are negative emissions, and what is their role for the 1.5°C goal?

6 What is meant by greenhouse gas neutrality?

7 What role does biodiversity play for the 1.5°C goal?

1 How is compliance with the 1.5°C goal measured?

The 1.5°C goal is with reference to the increase in the global mean temperature against a pre-industrial baseline. Because reliable temperature data has only been available since the middle of the 19th century, and because the input of carbon dioxide (CO_2) into the atmosphere was so low in the preceding period that it could hardly have affected the climate, the global mean temperature of the second half of the 19th century is taken to represent the 'pre-industrial era'.

To determine an increase in temperature, this historical value is referenced against today's global mean temperature, averaged over decades. Due to natural climate variability, a comparison with only one or very few years would not be valid. While the IPCC uses a 20-year average as a reference period, the World Meteorological Organization (WMO) defines the climate as the average weather over 30 years [7].

Scientific findings show that in the first 20 years of the 21st century, the global mean temperature was about 1°C higher than in the pre-industrial era.

For the year 2023, the average temperature increase was 1.46°C [8]; for the year 2024, it was even 1.6°C [20]. These were only two years and not the 20-year average, which is the IPCC's decisive reference value for determining whether the 1.5°C goal is exceeded. Nevertheless, a heated media discussion ensued about the failure to meet the 1.5°C goal.

2 Can the 1.5°C goal still be achieved?

In physical terms, it is still possible to meet the 1.5°C goal. Two opposite effects must be taken into account. On the one hand, the global ocean's thermal inertia means that it would continue to warm for years even if atmospheric greenhouse gas concentrations were to remain stable. On the other hand, if CO_2 emissions were to fall to zero very quickly, the ocean would continue to absorb CO_2 from the atmosphere until an equilibrium between the atmosphere and the ocean is reached. As a result of this process, the CO_2 concentration in the atmosphere may reach a level that is below the CO_2 concentration at the time of net zero CO_2 emissions. According to modelling calculations (as already presented in the 5th IPCC Assessment Report), these opposite effects are expected to balance each other out. In other words, if global CO_2 emissions were to be stopped today (and other climatically active gases and particles retained more or less the same concentrations), it can be assumed that the globally averaged surface temperature would remain roughly the same. This means that with the current average global surface temperature of just below 1.5°C, a physical possibility of meeting the goal theoretically exists. However, so close to the 1.5°C limit, this can no longer be predicted with certainty.

It is therefore only possible to calculate scenarios that (with a probability of 50 or 66 percent, for example) remain below a temperature limit that is above 1.5°C – or would return to 1.5°C after temporarily exceeding this threshold. All of these scenarios, which model compliance with the 1.5°C goal by the end of the century (usually after a temporary overshoot), calculate pathways under the following assumptions: (1) gross emissions must be reduced so drastically that the global community (2) reaches net-zero[3] CO_2 emissions by the middle of the 21st century and then (3) maintains net-negative[4] emissions for decades to come.

3 Net zero (or greenhouse gas neutral) refers to the Earth's climate footprint, which must be zero "on balance", i.e. all emissions caused by humans are avoided or removed from the atmosphere through reduction measures. The term is often also used for other greenhouse gases (methane, nitrous oxide, ozone, etc.).

4 Net negative emissions are achieved when more greenhouse gases are removed from the atmosphere (and permanently stored) than are released into the atmosphere in the same period. The concept of overshoot calculates with net-negative emissions in order to bring the temperature back to 1.5°C by the end of the century.

Given today's state of knowledge, these drastic emissions reductions can be deemed technically feasible. However, in view of the existing societal conditions, it is not realistic to expect they will be achieved[5]. Studies by the University of Hamburg show that social 'drivers' – including international agreements, social movements and climate protests, climate lawsuits, knowledge and media – support decarbonisation efforts, but are too weak to facilitate the necessary drastic reduction in emissions. The two drivers "consumer behaviour" and "corporate behaviour" even work against the goals of the Paris Agreement [4]. According to a new study, the social driver 'divestment from fossil fuels' has changed from a previously weak driver to a driver that is now working against the goals [16]. Ongoing substantial investments into fossil fuels (e.g., construction of coal and gas-fired power plants, the development of oil and gas fields) as well as climate-damaging subsidies mean that the goal of net-zero is increasingly beyond reach.

3 When will the 1.5°C goal be exceeded according to current scientific knowledge?

The latest IPCC Assessment Report[6] states that the 20-year average of global temperature increase is expected to exceed the 1.5°C threshold by the beginning of the 2030s. This will happen almost independently of emissions trends. Only if global CO_2 emissions were actually reduced to zero today, contrary to expectations (see FAQ 2), would the global mean temperature remain roughly the same and the 1.5°C threshold would presumably not be exceeded. A non-abrupt but tremendously rapid reduction in emissions (e.g., to zero by 2030) would probably delay the point at which the limit is exceeded or possibly even avoid exceeding it entirely.

4 How should a temporary overshoot of the 1.5°C goal be assessed?

The Paris Agreement does not specify a time frame for the temperature goals. The wording "holding the increase in the global average temperature to well below 2°C" and "pursuing efforts to limit the temperature increase to 1.5°C […]" (Paris Agreement, Art. 2) indicates that average global temperature increase should be maintained at or below these values. The currently prevailing interpretation assumes that the Paris Agreement also leaves room for temporarily exceeding this threshold (overshoot) and subsequent reduction to below 1.5°C.

The overshoot is to be made possible by "negative emissions". This would entail the active removal of enormous quantities of CO_2 from the atmosphere and its permanent and safe storage. According to the IPCC, an additional warming of 0.1°C corresponds to about 220 gigatonnes of cumulative CO_2 emissions.[7] Hence, reducing an overshoot back to 1.5°C would require the storage of hundreds of gigatonnes of CO_2. For comparison, annual global emissions from burning coal, oil, and gas presently amount to about 40 gigatons of CO_2 annually. In recognition of the current situation and the expected further development, many experts have now moved away from the expectation of "never above 1.5°C".

The IPCC scenario for the 1.5°C goal (SSP1-1.9) follows the logic of the overshoot. It models the transition to net-negative CO_2 emissions shortly after 2050, based on the current understanding of the socio-economic context as a condition for global warming to return to below 1.5°C by 2100. It should be noted that this scenario assumes that global emissions peak around 2020 before subsequently declining. This reversal in emissions trends has not yet been achieved. According to the current state of knowledge, a drop in the global mean temperature below 1.5°C warming by 2100 can still not be ruled out. However, this requires increasingly drastic emissions reductions with each additional year of delay, and is furthermore unrealistic given the expected costs for the necessary removal of CO_2 from the atmosphere.

5 See Fig. 5 in [17]
6 See Lee, Marotzke et al., Chapter 4, in [1]
7 see D1.1 in [2]

An overshoot and subsequent reduction to 1.5°C – if it could be achieved – does not guarantee that the state of nature and ecosystems could also be brought back to the level of a 1.5°C world. For example, Greenland ice lost during the overshoot phase would not be restored by simply returning to 1.5°C and forests destroyed by the increase in temperature would not come back.

Overshoot as a strategy for meeting the 1.5°C goal on the one hand fails to answer the question of whether the technical and political preconditions for the enormous associated removal of CO_2 are at all feasible. On the other hand, it is unclear whether and, if so, to what extent an overshoot would be socially "tolerable".

5 What are negative emissions, and what is their role for the 1.5°C goal?

Negative emissions can be achieved through the removal of CO_2 from the atmosphere and its permanent storage in natural or technical facilities. Under current emission pathways, it will not be possible to achieve the 1.5°C goal by the end of the century without negative emissions over the next few decades. All IPCC scenarios that comply with the goals of the Paris Agreement include negative emissions to some extent. By failing to address the underlying assumptions, this sends the disastrous signal that the goals can realistically be achieved. However, the later the trend reversal occurs, the more abruptly emissions would have to be reduced and ultimately become net-negative. This would require an extremely rapid expansion of technical facilities for CO_2 storage and the development of storage sites. Such models assume an enormous upscaling of technological applications, usually without any classification or with very optimistic assumptions about the costs, energy requirements, and material resources that would be involved.

It is also problematic that these technical approaches give the impression that changes in lifestyles and economic practices would not be necessary. The opposite is true. The reason for this is that large-scale CO_2 removal and storage would be associated with very high costs, enormous resource consumption, and further pressure on ecosystems (see FAQ 7). The cost of removing CO_2 directly from the atmosphere using chemical methods (direct air capture, DAC) is currently around 500 to 1,000 Euros per tonne of CO_2 [9,10]. The sum of these costs increases over time as long as current lifestyles and linear economies are maintained.

6 What is meant by greenhouse gas neutrality?

Article 4 of the Paris Agreement establishes an explicit time frame for achieving the goal of greenhouse gas neutrality and specifies that a "balance between anthropogenic greenhouse gas emissions by sources and removals by sinks" (Paris Agreement, Art. 4) should be achieved in the second half of the 21st century. The greenhouse gas neutrality target is therefore already a formal addition to the 1.5°C goal. The target is predominantly interpreted in such a way that not every greenhouse gas must be neutralized individually, but greenhouse gas neutrality must be achieved overall.

However, the term greenhouse gas neutrality is not clearly defined. This is due to the different climate effects of greenhouse gases such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and ozone (O_3), which absorb terrestrial infrared radiation to different degrees and in different wavelength ranges, have different atmospheric residence times, and are spatially distributed differently. In order to compare the climate impact of these greenhouse gases, a conversion factor is used – the "Global Warming Potential" (GWP). It sets the warming potential of one kilogram of emissions of a greenhouse gas in relation to one kilogram of CO_2 emissions (i.e., for CO_2 the GWP equals one).

However, a time horizon must be specified for the conversion. For less long-lived gases such as methane, the GWP differs considerably depending on the time horizon selected: methane has a GWP of around 30 for a 100-year time horizon, but it has a GWP of over 80 for a 20-year time horizon. The conversion is even more complicated for short-lived greenhouse gases such as ozone. If greenhouse gas neutrality is applied individually for each greenhouse gas, then the conversion problem becomes superfluous. When it comes to overall green-house gas neutrality with the possibility of cross-compensation (e.g. CO_2 removal to offset methane or nitrous oxide emissions), however, a clear working definition of "greenhouse gas neutrality" is required in order to facilitate consistent governance.

Apart from greenhouse gases, other anthropogenic influences are also relevant to the climate. This applies in particular to particulate matter, such as sulphate, nitrate and soot particles, which have both a cooling and, to a much lesser extent, a warming effect. The net cooling effect of particulate matter is around 0.5°C compared to pre-industrial times[8] and is therefore significant compared to current global warming caused by CO_2 of around 1°C. However, this "masking" effect of particulate matter only applies to the global average. Compared to CO_2, particulate matter is spatially distributed differently and therefore, contributes substantially to regional climate change. Meeting the goals of the Paris Agreement – and effective climate protection in general – therefore also requires that the emissions of these climate-impacting pollutants be taken into account.

7 What role does biodiversity play for the 1.5°C goal?

Climate and biodiversity are closely connected, which is why some speak of "twin crises". Climate change increases the risks to biodiversity in natural and managed habitats. At the same time, with their biodiversity, natural and managed ecosystems play a key role both for the release and the sequestration of greenhouse gases and for climate adaptation. Land ecosystems and oceans together currently absorb more than 50 percent of anthropogenic CO_2 emissions. In the oceans, a large proportion of CO_2 uptake occurs through physical dissolution, at the cost of ocean acidification. On land, storage takes place in vegetation and soils. These contributions of nature, which mitigate climate change, are already being compromised by the destruction of ecosystems and their biodiversity as a result of ongoing climate change and other human activities [11].

At the same time, intact ecosystems play a crucial role in climate adaptation because such ecosystems are more resilient to climate change. A prominent example is Germany's forests, where large areas of spruce monocultures have been dying off since the drought of the century in 2018, while intact and biodiverse ecosystems are less affected.

The increasing damage to ecosystems caused by land use changes and other interventions in natural carbon reservoirs such as forests, peatlands, or soils often transforms ecosystems from CO_2 reservoirs into CO_2 sources - and thus into additional drivers of climate change. Two examples: Over the last 20 years, anthropogenic deforestation in Brazil has led to more annual CO_2 emissions on average than annual CO_2 emissions in Germany [12]. In Germany, the draining of natural peat bogs has led to considerable CO_2 emissions, which today correspond to around seven percent of Germany's total emissions [14].

Measures for the protection, restoration and sustainable use of terrestrial and marine ecosystems offer multiple benefits: (1) they protect biodiversity, (2) support adaptation to the consequences of climate change and (3) protect the climate by capturing carbon. The conversion of forests in Germany to systems with more tree species, for example, leads to risk diversification, the preservation of biodiversity, and the long-term safeguarding of wood production.

8 see Fig. 6.12 in [1]

Measures such as reforestation can lead to further CO_2 uptake as part of nature-based solutions and contribute to negative emissions. Nevertheless, it must always be considered very critically whether, on the one hand, CO_2 sinks are permanent (and cannot be destroyed by fire, for example) and, on the other hand, whether they negatively impact biodiversity and other sustainability goals. Storage capacities of billions of tons of CO_2 are calculated for various nature-based solutions. However, (1) different quantitative estimates are often far apart, (2) the fundamental processes are not yet sufficiently understood in some cases (e.g. for some marine measures), and (3) conflicts with other sustainability goals, such as food security, are often not adequately taken into account [10].

Technical CO_2 removal is also problematic with respect to land use, and land-based measures can (further) fuel land use conflicts. Some scenarios for large-scale bioenergy plantations with CO_2 injection (bioenergy with carbon capture and storage, BECCS) assume more than one billion hectares would be necessary, which amounts to around one hundred times the area used for agriculture in Germany. A one-sided focus on the specific function of climate protection, which is just one of many services provided by ecosystems, combined with a strong focus on afforestation, must also be viewed critically. Many so-called *key biodiversity areas* are located in open land systems and are currently threatened by afforestation projects [13].

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