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Overshoot: Returning to 1.5°C Requires Net-negative Emissions Targets

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Global warming is set to rise above 1.5°C by the early 2030s. Returning to 1.5°C before the end of the 21st century would not prevent all harms resulting from a period of excess temperatures, but it would reduce risks when compared to permanent warming above 1.5°C. Limiting the magnitude and duration of this period of "overshoot" to manage climate risks requires enhanced near-term mitigation efforts to ensure that warming peaks well below 2°C, followed by sustained net-negative carbon dioxide (CO_2) and potentially net-negative greenhouse gas (GHG) emissions globally. This presents new challenges to international climate policy in efforts "to keep 1.5°C alive". For frontrunners such as the European Union (EU), this will require reframing "net-zero" as a transitional stage towards net-negative GHG emissions rather than an endpoint, and developing policy instruments that are able to deliver this.

In 2015, the United Nations Framework Convention on Climate Change (UNFCCC) created a long-term temperature goal with the adoption of its Paris Agreement, namely "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".

Ten years later, global emissions of CO_2 and other GHGs are at their highest levels ever. It has now become virtually impossible to avoid exceeding 1.5°C, even when considering that global temperature goals do not refer to individual years, but 20-year running averages. Reaching and then exceeding 1.5°C is expected to happen by the early 2030s, regardless of the emissions reductions that may be achieved in the coming years. This was already indicated in the *Synthesis Report* of the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) in 2023, and recently confirmed in the *Emissions Gap Report* issued by the United Nations Environment Programme (UNEP).

This growing realisation — catalysed by a marked shift in UN officials' communications in late 2025 — confronts Parties to the UNFCCC with a choice either to aim for stabilising warming between 1.5°C and well below 2°C, or to try to achieve a reversal of global warming back to 1.5°C, after a period of overshoot that may last multiple decades (see Figure 1).

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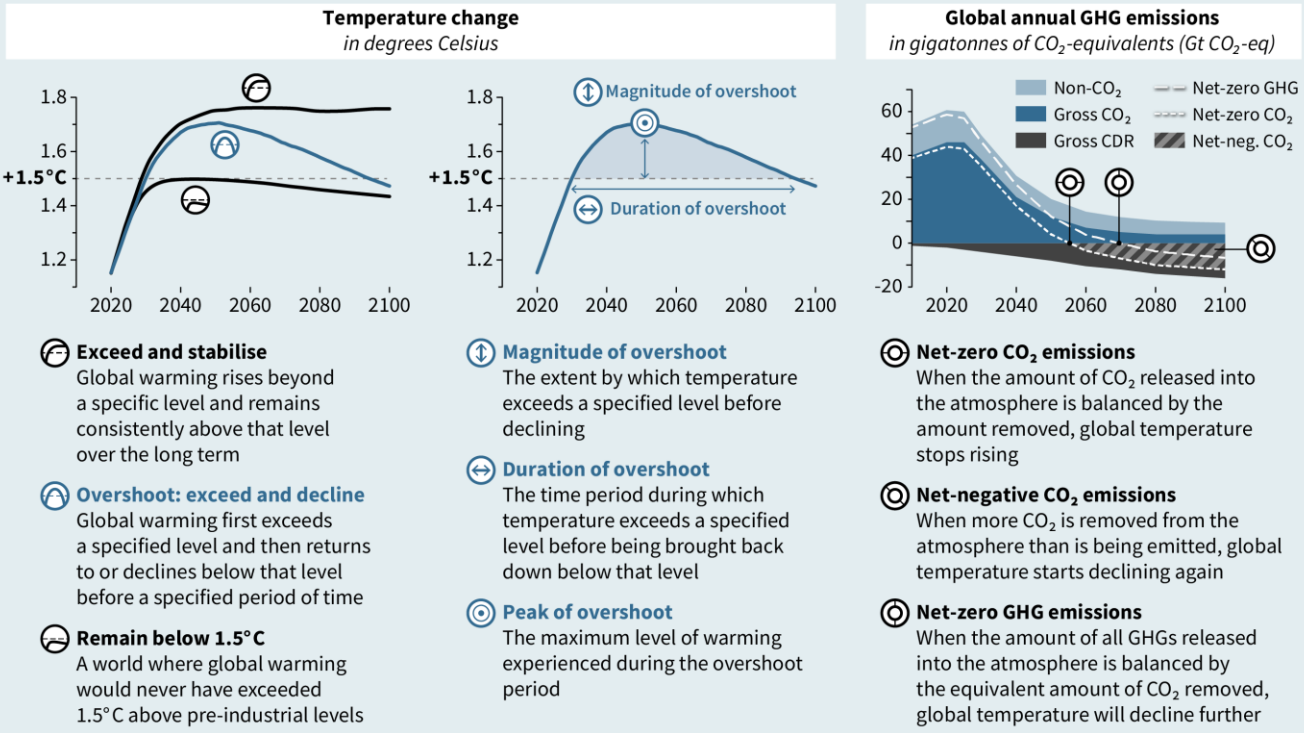
Figure 1

Temperature overshoot and associated emissions trajectory:
Ending a temperature overshoot period requires net-negative CO_2 emissions



Source: Annual Review of Environment and Resources (2025); https://doi.org/10.1146/annurev-environ-111523-102029

Temporary overshoot as a concept

The physical climate system puts clear constraints on human activities that are consistent with a peak and decline in the global average temperature. Global warming will be halted only when global net CO_2 emissions from human activities reach zero, with peak warming determined largely by cumulative net CO_2 emissions up to that point. A subsequent decline in global warming, which is needed to return to 1.5°C, relies on sustained net-negative CO_2 emissions from human activities, with total removals outweighing residual emissions of all long-lived GHGs. Reducing emissions of short-lived climate forcers, in particular methane (CH_4), would also help limit peak warming. Further reductions beyond 2050 could contribute to the subsequent decline in temperature. In this sense, achieving net-zero GHG emissions globally, often dubbed "climate neutrality" in climate policy circles, implies net-negative CO_2 emissions, leading to a slight decline in the global temperature.

"Magnitude" and "duration" of an overshoot thus depend on the emissions profile both up to and after exceeding 1.5°C. The faster the world reaches net-zero CO_2 emissions and the lower the rate of CH_4 emissions, the less the exceedance of 1.5°C. The deeper the level of subsequent net-negative CO_2 emissions, the faster the return to 1.5°C (Figure 1).

Current scientific understanding suggests that net-negative CO_2 emissions would reduce global warming at roughly the same rate as ongoing emissions increase it. In quantitative terms, reducing the global average temperature by just 0.1°C would require about 220 gigatonnes (Gt) of net-negative CO_2 emissions. Gross amounts of carbon dioxide removal (CDR) will need to be even greater, given that it is impossible to reduce

CO_2 emissions fully to zero (hence the *net* in net-zero). For comparison: 220 Gt amount to five years of current annual emissions, and 100 years of current annual CDR levels (which are almost entirely in the form of conventional afforestation and reforestation). Novel methods, for example, bioenergy combined with carbon capture and storage (BECCS) and the direct capture of CO_2 from the ambient air and subsequent storage (DACCS), are both only in the early stages of development.

Risks and impacts

Exceeding 1.5°C will result in greater impacts on humans and ecosystems than if global warming had remained below that level, and it presents greater climate risks, including from extreme weather, ecosystem degradation, and socio-economic disruptions. Limiting overshoot — that is, limiting by how much and how long the world exceeds 1.5°C in the first place — remains the critical step in addressing these threats.

It is much less clear at this point how much a subsequent decline in temperature would reverse different climate risks. In principle, reducing global warming will help limit all physical climate changes — either because they are reversed (e.g. the frequency and intensity of heatwaves), or because the changes will not be as significant as they would have been had the global average temperature remained elevated above 1.5°C (e.g. sea level rise). However, the risk from climate change arises not merely from physical changes in climate, but from the interaction of such changes with the exposure and vulnerability of human society and ecosystems. Regions that experience extreme climate events during the overshoot phase could face long-term social and economic consequences, since climate-related impacts such as malnutrition, poverty, and infrastructure damage — along with weakened institutions and strained financial capacity — are likely to persist well beyond peak warming.

For many ecosystems, a period of excess temperatures could disrupt species composition and food webs that may be irreversible or take many human generations to recover. However, species extinction will be irreversible, even if restoring a former ecosystem state were possible.

A world that returns to global warming of 1.5°C will be a significantly altered and more damaged world than if this level of warming had never been exceeded.

Political significance of overshoot

By now, relying on some form of overshoot trajectory has become the only way to "keep 1.5°C alive". We do not know yet whether the UNFCCC will explicitly adopt this vision in future decisions. So far, there has been no serious discussion about climate system impacts, political responsibilities, and future policy responses resulting from exceeding — and potential returning to — 1.5°C. This is even though the term "overshoot" can be found in many UNFCCC documents — it is used to refer to the nomenclature of IPCC-assessed mitigation pathways for achieving 1.5°C by 2100 but does not deal with its substance yet.

Taking overshoot seriously would catalyse two paradigm shifts in global climate policy. Initially, the more obvious one seems to be the conceptual introduction of a phase of managed temperature decline, enabled by aiming for net-negative CO_2 emissions globally, potentially to be followed by net-negative GHG emissions. This would immediately raise the question of who is in charge to lead the way into net-negative territory. Under the UNFCCC's core principle of *Common But Differentiated Responsibilities* (CBDR), the answer can only be that developed countries will have to continue to be the frontrunners by adopting and pursuing national net-negative targets, which entails stringent emissions reductions while rapidly upscaling CDR. If 1.5°C is to remain the core temperature goal, then net-zero can no longer be seen as an end point but only as a transition point in climate policy.

However, the more pressing and maybe more disruptive shift will come with the

inevitable, yet contentious introduction of a new interim — and perhaps only implicit — temperature target: peak warming. Although there has not been any discussion so far, the global climate debate is likely to focus on the 1.7—1.8°C range. Everything below 1.7°C does not seem feasible anymore. Everything above 1.8°C would be too high a level to achieve a return to 1.5°C in this century and also increase the potential for warming to exceed even 2°C, once scientific uncertainties are taken into account.

Least-developed countries can be expected to call for enhanced financial flows to cover additional damages linked to the exceedance of 1.5°C, even if only thought to be temporary. Since countries such as China, India, and Saudi Arabia seem to favour "well below 2°C" as the focal point for global climate policy, the UNFCCC may never be able to reach consensus on an exact peak warming target. But even with ambiguity concerning the intended peak level, reaching net-zero CO_2 emissions would remain the global focal point for climate action as a prerequisite for halting further warming.

Challenges for EU climate policy

If the EU really wants "to keep 1.5°C alive", it will need to adopt and elevate the concept of a temperature overshoot target and proactively deal with its consequences for long-term emissions targets, both in multilateral fora and within Europe. Failing to do so will inevitably lead to the impression that "1.5°C overshoot" is nothing more than an interesting thought experiment, and that stabilising global warming well above 1.5°C is by now the best the world can still hope for.

At the global level — whether it is the UNFCCC, the G20, or the G7 — the overshoot concept can only gain political credibility if developed countries underscore it by first committing to reaching and sustaining net-negative emissions. The requirement for frontrunners to enter net-negative territory holds, even if global ambition remains limited to net-zero GHG emissions, given the uneven distribution of responsibilities and capacities. This will inevitably trigger a renewed debate about global burden-sharing (including the role of emerging economies such as China) and international collective efforts to drastically upscale CDR in the medium- to long-term while managing risks from adverse side-effects.

Within the EU, this would first and foremost entail setting a quantified net-negative GHG emissions target for 2060, as already implicitly foreseen in the European Climate Law, but currently only applied by a single member state (Denmark, with -110% by 2050). This will refuel burden-sharing conflicts within the EU, where economically less advanced member states may demand that countries such as Germany, France, and Denmark take the lead and commit to deep levels of net-negative emissions, while Central and Eastern European countries — and those with high shares of hard-to-abate residual emissions — may follow only later. The same applies to economic sectors, where mitigation pathway modelling indicates that the European power sector will deliver net-negative emissions early on while agriculture stays net-positive (see SWP Research Paper 8/2020). Furthermore, the EU will be forced to develop viable macroeconomic and policy frameworks that advance beyond the standard "polluter pays" principles and simple win-win narratives. Going deeply net-negative will turn carbon pricing from a source of income into a significant financial burden; so far, no convincing vision has been presented that illustrates how entering net-negative territory will give frontrunners a competitive advantage in the long run.

The EU has been a pioneering force in international climate policy for more than three decades now, even within developed-country groupings such as the G7. Reaching net-negative emissions will be the next frontier that multiplies many current policy challenges. Making serious plans to enter this territory will provide a crucial example for the rest of the world.

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