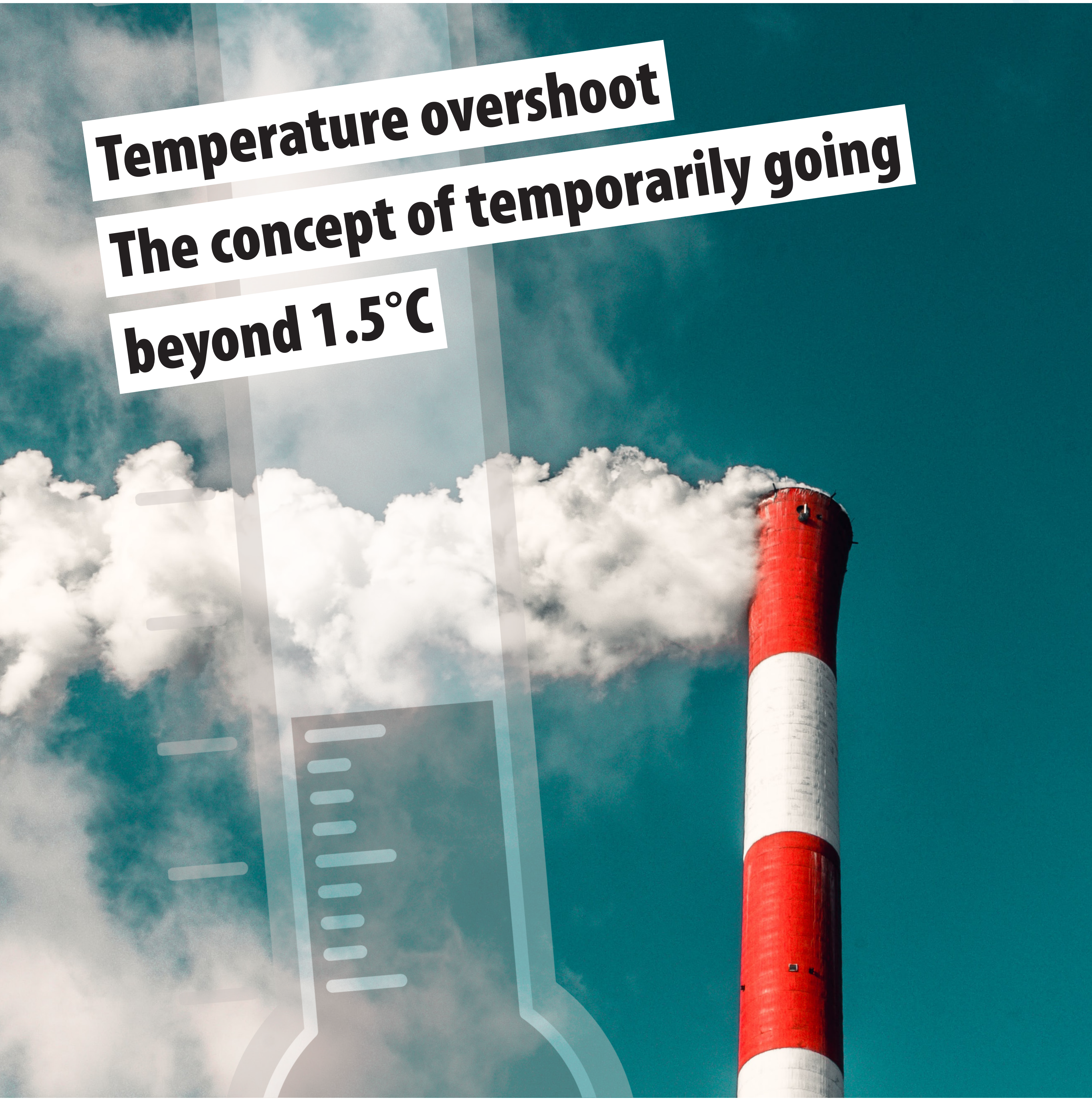
Temperature overshoot
The concept of temporarily going beyond 1.5°C



AirClim

Air Pollution & Climate Secretariat

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Overshoot?

In the 2015 Paris Agreement, countries agreed to make an effort to limit temperature rise to 1.5°C as going beyond that temperature limit would bring severe negative impacts, in particular for those most vulnerable. While not explicit in the text, it is generally understood that the objective is to ensure temperature rise is limited to 1.5°C by 2100. As substantial climate action has been delayed over and over again, almost all 1.5°C consistent scientific pathways for the future foresee peak temperatures potentially going beyond 1.5°C during the course of the century, with temperatures being reduced to 1.5°C or below by 2100. This concept of average temperature rise going temporarily beyond 1.5°C and then being reduced is referred to as temperature overshoot.

Almost unavoidable?

Many scenarios have been developed to show how the world could limit temperature rise to 1.5°C by the end of the century. The IPCC's Special Report on Warming of 1.5°C identified three classes of 1.5°C consistent pathways:

1. Below 1.5°C pathways: limiting peak warming to below 1.5°C during the entire 21st century with 50–67% likelihood;
2. Low overshoot 1.5°C pathways: limiting median warming to below 1.5°C in 2100 and with a 50–67% probability of temporarily overshooting that level earlier, generally implying peak warming of 1.5°C or less;
3. High overshoot 1.5°C pathways: limiting median warming to below 1.5°C in 2100 and with a greater than 67% probability of temporarily overshooting that level earlier, generally implying peak warming up to 1.9°C.

Both the first and the second group are called "as likely as not pathways' as they both have a reasonable chance of temporarily exceeding 1.5°C, though likely by no more than 0.1°C. However, to be fair, 90% of all 1.5°C consistent pathways assessed by the IPCC would include some form of overshoot, thereby indicating, in light of the huge gap between current action and these pathways, that a temporary overshoot is almost unavoidable.

Limitation needed

The concept of potentially temporarily overshooting 1.5°C needs to be looked at carefully, as:

1. Even temporary overshoots can lead to permanent damage, and the higher the overshoot the greater the risk;
2. The concept of bringing down temperature is uncertain and debatable as it assumes not only stringent near-zero emissions but also substantial emission removals through technologies which are controversial;
3. The concept of achieving (substantial) net negative emissions at some time in a brighter (but unproven) future could reduce the pressure on the necessary stringent short-term emission reductions.

Irreversible impacts will happen

Although a range of impacts that might occur if we overshoot 1.5°C are generally considered to be reversible once temperatures can be lowered, other impacts, such as sea level rise, loss of ecosystem functionality, increased risks of species extinction as well as loss of glaciers and permafrost are considered not to be reversible over timescales of decades to millennia; furthermore, the risk of abrupt changes and tipping points increases with higher warming levels and longer overshoot periods.

- **Sea level rise:** global sea level rise shows a slow and delayed response to atmospheric warming and greenhouse gas emissions. It will therefore continue for centuries to millennia even after temperatures have peaked. There is a quasi-linear relationship between the duration of the overshoot and sea-level rise, adding around 4 cm of sea-level rise per 10 years of overshoot above 1.5°C. Thermal expansion of ocean water and ice sheet mass loss are among the main drivers of sea level rise. Crossing ice sheet tipping points, for the Greenland or Antarctic ice sheets for example, may substantially increase the irreversible rise in sea level;
- **Glacier loss:** glacier loss may not be reversible on timescales of decades to centuries. Glaciers are a major source of freshwater for billions of people around the world. After an initial increase in glacier run off, there will be a substantial risk of water scarcity in the run-off basins;
- **Ecosystem and species loss:** shifting habitats and extreme events will lead to species loss and extinction risks that might be irreversible. Ecosystems and species not only need to adapt to a rapid rise in temperatures but would be faced with the challenge of coping with the lower level of warming post-overshoot. Coral reefs are projected to decline by 70–90% with 1.5°C of warming and virtually all (>99%) would be lost under 2°C. Similarly, extreme events, such as extensive droughts and resulting fire risks, will eliminate forest ecosystems (such as the Amazon rainforest) that will likely not regrow to the same extent later, even if temperatures are reduced to previous levels;
- **Permafrost:** permafrost and its frozen carbon content will be lost during the warming phase and beyond. Because the loss of carbon due to thawing permafrost is irreversible over hundreds of years, overshoot pathways will have a distinct impact on these soils and the released carbon will further accelerate warming.

Our capacity to reduce temperature is limited

To reduce temperatures, the rate of removal of carbon must exceed emissions and create a state of so-called net negative emissions. This obviously requires that emissions must be reduced to near zero, and that removals are increased to a level above what is still being emitted. The technologies that would enable such removals are summarised under the term Carbon Dioxide Removal (CDR). While some potential for sustainable CDR deployment is identified in the literature, reliance on CDR at large scale comes with its own risks, uncertainties and side effects. CDR usually involves two processes: 1) the capture and removal of atmospheric CO_2 and 2) the subsequent storage of the captured CO_2. CDR methods differ substantially in the mechanism of CO_2 capture and the type of storage. Approaches such as Afforestation and Reforestation (A&R), Soil Carbon Sequestration (SCS), Enhanced Weathering (EW) and Biochar (BC) enhance the amount of CO_2 that is taken up by plants, minerals and nutrients and store it in land or ocean stores. Bioenergy with Carbon Capture and Storage (BECCS) and Direct Air Carbon Capture and Storage (DACCS) on the other hand remove CO_2 with explicit technological infrastructure and transport the captured carbon dioxide to geological reservoirs.

Sustainable CDR deployment of any of these methods at scale is unproven and associated with multiple feasibility and sustainability constraints. Wide-ranging side effects of CDR methods can influence their potential for removing and permanently storing CO_2, and affect the achievement of sustainable development goals for water, food and biodiversity, for instance. The main concerns relate to large land, water and financial requirements and constraints in long-term storage of removed CO_2. The carbon capture and storage technology linked to BECCS and DACCS lacks sustainability, technological readiness and economic sustainability. BECCS is further constrained due to its especially high land and water requirements and related concerns of competition with food crops, damage to biodiversity and intense fertiliser use, while DACCS requires a lot of energy. All in all, only nature-based solutions offer real opportunities for increasing removals, but using nature to store carbon needs to be seen as a co-benefit from increased protection and restoration of the Earth's ecosystem.

Another key overshoot dimension that needs to be reflected upon is the length of the overshoot and its linkage to the assumed CDR potential. Even if we assume speculative amounts of yearly CDR potentials of 10 $GtCO_2$ per year or more the actual pace of temperature reductions would be around 0.05°C per decade. This implies that the reversal of any temperature overshoot would take decades and for high overshoots imply multi-decadal exceedance of 1.5°C. Figure 3 shows the interdependency of the magnitude of the overshoot and the length of the overshoot assuming 0.05°C of temperature reductions per decade could be realised. For more realistic levels of maximum attainable CDR, the reversal timescales would be even longer.

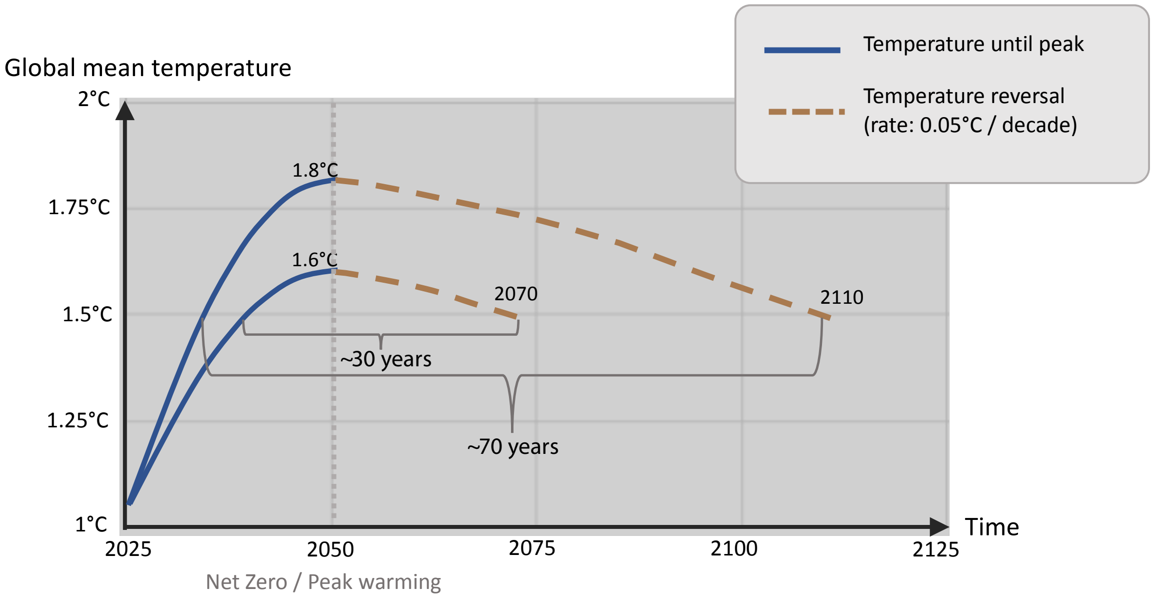

Figure 1: Illustration of the interdependency of overshoot magnitude and overshoot length. Best estimate pace for temperature reductions with high CDR deployment is from Rogelj et al., 2019.

Conclusion

Given that going beyond 1.5˚C, even for a short while, will bring irreversible impacts, in particular to those most vulnerable, and given that the concept of achieving net negative emissions still has a lot of uncertainties, the world's governments should do whatever they can to ensure temperature rise peaks at 1.5˚C or below. This will need radical action to reduce and phase out greenhouse gas emissions in the very short term.

by Wendel Trio
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