The road (back) to Paris

A science-based reflection on where we stand and the road ahead

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Where we stand…

- To avoid exceeding 1.5°C of global mean surface temperature rise, global greenhouse gas (GHG) emissions needed to bend no later than 2020, halving CO_2 emissions by 2030 and reaching net-zero CO_2 by 2050. Now, in 2025, we must admit failure: global GHG emissions continue to rise. As a result, long-term global warming will almost inevitably exceed 1.5°C within the next decade.

- This does not have to be permanent. If we make the right choices going forward, we can still change course and bring temperatures back below 1.5°C by the end of this century—an 'overshoot' pathway. Such a future remains in reach, but it will be extremely challenging. It requires both deep and rapid global emissions reductions *and* massive scaling up of carbon dioxide removal technologies and practices (CDR).

- Returning to below 1.5°C should remain the goal for all international efforts to avoid dangerous climate change. Since the Paris Agreement took effect, the science has become even clearer about increasingly unmanageable risks from extreme weather events beyond 1.5°C. Warming is driving increases in extreme heat, fires, droughts, water scarcity, flooding and soil degradation, impacting the lives and livelihoods of billions of people. Each tenth of a degree will render these climate and natural extremes even more deadly, costly and unmanageable. For many systems and communities, the capacity to adapt is already at its limit.

- Beyond 1.5°C we enter the high-risk zone for crossing tipping points. Multiple Earth system components that regulate the stability of the global climate system and provide life support for people, are likely to cross tipping points. These include collapse of the Greenland and West Antarctic Ice Sheets, abrupt thawing of permafrost, collapse of the Labrador sea current and the Barent sea ice, and collapse of tropical coral reef systems. If loss of biodiversity and forest cover, and changes in hydrology are factored in (together with heat from climate change), there is even a high risk that even the Amazon basin will tip already between 1.5°C and 2°C. The latest science shows that collapse of the Atlantic Meridional Overturning Circulation (AMOC), which drives the Gulf stream that heats Europe, can no longer be considered a low-likelihood event, even within this century.

- Some tipping processes, such as collapse of the AMOC or dieback in the Amazon rainforest, would disrupt the linear relationship between GHG emissions and global warming, leading to self-amplifying global warming.

- The lower the overshoot, the less stress we will put on our Earth's systems and the greater our chances of returning to below 1.5°C - **every tenth of a degree matters**. The best and only tool for limiting the overshoot is immediate and significant emissions reductions.

- Returning to the safe operating space of the Earth system depends not only on returning global warming below safe limits, but on protecting and restoring all life-supporting functions of the Earth system. This means also returning freshwater use, land-system change, biodiversity loss and other key indicators to within planetary boundaries.

The road ahead…

1. Meeting this challenge requires massive expansion of clean energy solutions and electrification of many parts of our economies as well a rapid elimination of deforestation and reduction in agricultural emissions. We need to accelerate the transition away from fossil fuel-based energy, switch to healthy, sustainable diets, and preserve and restore natural carbon sinks. But, we will need to do more.

2. As of 2025, modelled pathways of highly ambitious decarbonisation see GHG emissions roughly halved by 2035, and a transition to net-zero GHGs around 2060. The transformation of the global economy implied by these numbers is significant, requiring annual reductions of 5% starting in 2025 (removing 2-3 billion tonnes of CO2eq/year from the global economy) – marginally less than the drop in global emissions in the first year of the COVID-19 pandemic. This must involve transforming the global food system from the single largest source to a carbon sink within the next 10-20 years, while at the same time safeguarding the carbon uptake capacity in intact nature on land and in marine systems.

3. Cutting emissions can slow the pace of warming, but it will not stop until we reach net zero GHG emissions. If we take a high-ambition path to net zero, the peak in global warming could be limited to roughly 1.7°C above the pre-industrial level. Returning to below 1.5°C would then require cumulative carbon dioxide removal of at least 400 billion tonnes – the equivalent of 10 years of current global emissions.

4. Any delay in emissions reductions comes at a high cost. The five year delay in reaching peak emissions from 2020 to 2025 means removing 200 billion more tonnes of carbon than without the delay. It burdens current and future generations with tens of trillions of dollars in additional CDR costs. Future delays will result in a higher peak temperature, leading to greater human suffering and an even higher chance of crossing tipping points. As a rule of thumb, each additional 5 year delay of halving global CO_2 emissions, e.g. by 2040 rather than 2035, could add another 200 billion tonnes of CO2 emissions and 0.1°C warming. Each time targets are not met, we place ourselves in a more dangerous, even riskier situation. Miss *this* chance and we will soon be facing locked-in peak temperatures beyond 2°C.

5. We have no guarantee that CDR can be ramped up to anywhere near the required levels, both in terms of speed and magnitude. We do know, however, that there are upper limits to how much CO_2 can be removed, arising from questions of social acceptability, economic feasibility, environmental impact and competition for productive land. Preservation and enhancement of natural carbon sinks will have to be complemented by technical CDR, such as direct air capture or biomass with carbon capture and storage, at the scale of a few billion tonnes per year to reach net zero CO_2 by mid century. Since these are still in a very early stage of development, upfront investments are needed now to have any chance of reaching the required CDR capacity by mid-century.

6. There is a risk that we are underestimating the climate system's response to human emissions. During the entire industrial era, Earth's biophysical capacity to buffer the energy imbalance caused by anthropogenic GHGs, has been remarkably high and stable. 50% of CO_2 has been absorbed by intact nature on land and in the ocean. 90% of heat has been absorbed by the ocean. The current climate crisis results from just 1% of the total energy imbalance ending up in the atmosphere. However, current observations may be revealing the first signs of Earth's resilience weakening. Over the past decade, temperature rise appears to be

accelerating. Cloud, albedo and carbon feedbacks may be amplifying warming. Such self-amplifying feedbacks between land, ocean and atmosphere could mean that the climate is more sensitive to rising GHG emissions, meaning peak temperature might be driven even higher than we currently expect. In this case, CO_2 removal could also prove less effective in reducing global warming than expected, resulting in a longer period of overshoot above 1.5°C and even more CDR required to return below 1.5°C.

7. As the Earth is now on track to continue warming until at least mid century, ambitious adaptation planning is more essential than ever. Adaptation efforts should plan for a likely warming range reaching up to at least 2°C by 2050–this upper bound is relatively insensitive to the mitigation decisions taken in the near term. However, we also have to keep low-probability, high-impact warming risks in mind. Such risks would strain the limits of adaptation, and successful adaptation cannot be taken for granted. The best defence is to also pursue the highest possible ambition on adaptation, putting vulnerable communities in the strongest possible position to buffer against change.