Can we limit global warming to 1.5°C?

ARC Centre of Excellence for Climate Extremes Briefing Note 15

- The Paris Agreement requires countries to commit to reducing their greenhouse gas emissions to ensure that the global average temperature remains less than 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C.
- In 2018 the Intergovernmental Panel on Climate Change concluded that limiting warming to 1.5°C is extremely challenging.
- The latest science, viewed alongside continuing increases in global greenhouse gas emissions, suggests that limiting warming to 1.5°C is now almost certainly infeasible. It would now require not only rapid emission reductions, but also the large-scale removal of carbon dioxide from the atmosphere. There is no evidence that this can be achieved at sufficient scale to meet the 1.5°C target.
- The consequences of 1.5°C of warming are smaller and can be adapted to more easily than those of 2.0°C warming or more. Aggressive cuts in greenhouse gas emissions that strive to limit warming to 1.5°C will make adaptation easier and less costly, even if we are ultimately unable to limit warming to this level.

How are we tracking towards limiting global warming to 1.5°C?

The legally binding Paris Agreement came into force in 2016. It requires signatory countries to strengthen the global response to the threat of climate change by 'holding the increase in global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C'. In 2018, the Intergovernmental Panel on Climate Change (IPCC), the authoritative UN body charged with assessing our knowledge of climate change, released a special report that highlighted the scale of the challenge of meeting the 1.5°C target[1]. Firstly, rapid transitions at an unprecedented scale in energy, industrial systems, infrastructure and land use would be required to reduce greenhouse gas emissions dramatically by 2030. Further emissions reductions in the following decades as well as removal of a significant amount of carbon dioxide (CO_2) from the atmosphere over the 21st century would also be needed, almost certainly requiring the use of new technologies that may not be feasible to deploy at sufficient scale.

Since the publication of the IPCC's special report, emissions of greenhouse gases into the atmosphere have continued, and even increased (Figure 1). Annual global emissions of CO_2 for 2018 and 2019 exceeded 42 billion tonnes per year and were the highest annual emissions of CO_2 ever recorded[2]. Although emissions in 2020 fell by 7% due to the response to the COVID-19 pandemic, this fall in emissions is too small and too temporary to significantly slow global warming[3], and global emissions are already rising again following easing of COVID-19 restrictions. The International Energy Agency (IEA) projects that global energy demand in 2021 will exceed its 2019 level, resulting in a 4.8% increase in emissions from energy generation alone between 2020 and 2021[4].

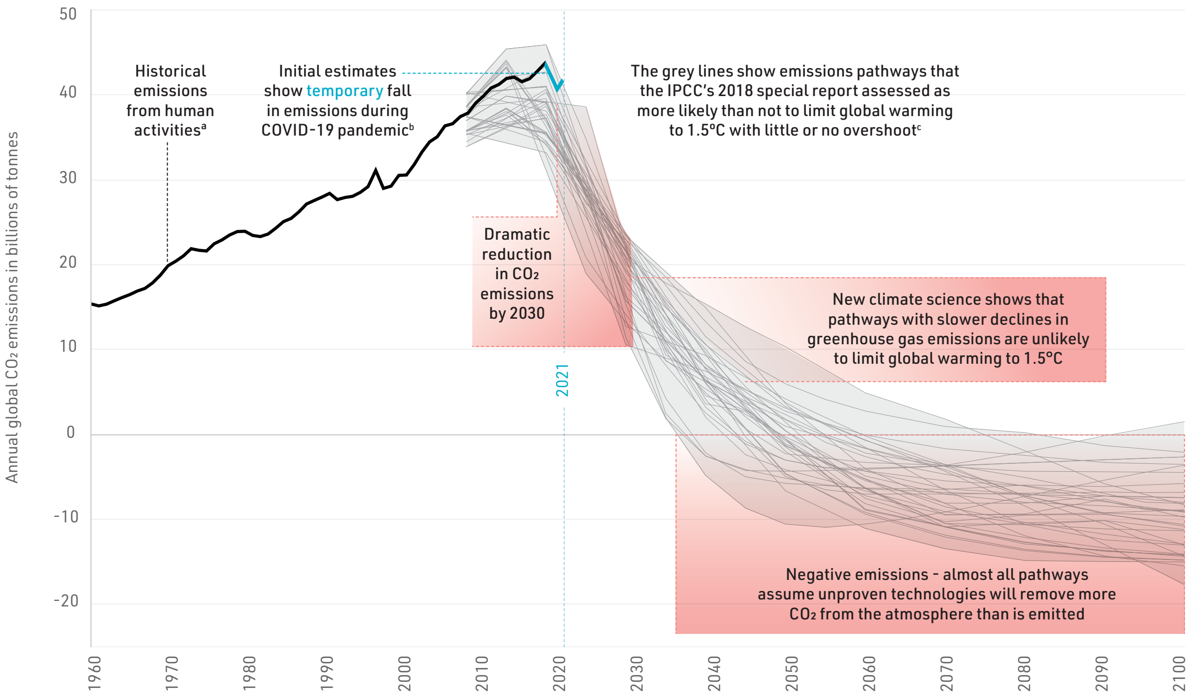
The global mean temperature for 2020 was 1.2 °C above the 1850–1900 average[5] and some analysts have concluded that the 1.5°C target is no longer possible. Australia's Climate Council recently stated that 'Multiple lines of evidence strongly suggest the global average temperature rise will exceed 1.5°C during the 2030s'[6]. Other assessments disagree, indicating that it is still possible to limit warming to 1.5°C if governments chose to take sufficient action to reduce greenhouse gas emissions[7].

What must be done in the future to limit global warming to 1.5°C?

If warming is to be limited to 1.5°C, there is a need to reduce greenhouse gas emissions dramatically, starting immediately. Almost all proposals consistent with limiting warming to 1.5°C also involve actively extracting CO_2 from the atmosphere and storing it securely, so that emissions are net zero around 2050. The more slowly we reduce our emissions over the coming decades, the more CO_2 we will need to extract from the atmosphere later in the century.

The IPCC's special report concluded that extraction of CO_2 at sufficient scale to offset our further emissions 'is subject to multiple feasibility and sustainability constraints'. More recently, the IEA published a detailed roadmap for the global energy sector to achieve net zero emissions and highlighted that new technologies in capturing and storing atmospheric CO_2 will need to be developed and deployed[8]. There are many proponents of CO_2 extraction and storage technologies and some technologies have potential[9]. However, there are currently few commercial-scale carbon capture and storage projects under way (e.g. only one in Australia – Chevron's Gorgon project in Western Australia). Relying on our ability to deploy costly and yet-to-be-proven carbon drawdown technologies on a large enough scale to avoid dangerous climate warming is a high-risk strategy. Recent analysis lead by the Potsdam Institute for Climate Impact Research has suggested that the IPCC's report was unrealistically optimistic in some of its assumptions about the potential for carbon capture and storage[10]. The technological CO_2 removal strategy also does not remove the need for rapid emission reductions in the short term and a transition to net zero emissions within coming decades.

Pathways for global CO_2 emissions thought by the 2018 IPCC report to limit global warming to 1.5°C



a - Emissions from fossil fuel use, industrial processes and land use change from Global Carbon Project (2020). Supplemental data of Global Carbon Budget 2020 (Version 1.0). https://doi.org/10.18160/gcp-2020
b - 2020 value estimated by Global Carbon Project (2020), 2021 value is a best current estimate assuming 2020 land use emissions and an estimate of change in fossil fuel emissions from International Energy Agency (2021) Global Energy Review 2021. https://www.iea.org/reports/global-energy-review-2021
c - Data from Huppman et al. (2019). IAMC 1.5°C Scenario Explorer and Data Release 2.0 hosted by IIASA. https://doi.org/10.5281/zenodo.3363345, data.ene.iiasa.ac.at/iamc-1.5c-explorer

Figure 1. Pathways for global CO_2 emissions thought by the 2018 IPCC report to limit global warming to 1.5°C. Model results estimated that each of these pathways had a greater than even chance of limiting global warming to 1.5°C with little or no overshoot. Also shown are historical emissions from human activities, including the recent temporary fall in emissions during the COVID-19 pandemic.

How does the latest climate science affect the feasibility of limiting warming to 1.5°C?

Our immediate and future greenhouse gas emissions are clearly critical in determining whether the ambition of limiting global warming to 1.5°C is achieved. The IPCC's special report presented a set of pathways for global emissions consistent with limiting global warming to 1.5°C (Figure 1). Model results estimated that each of these pathways had a greater than even chance of limiting global warming to 1.5°C with little or no overshoot. How the climate system behaves in response to past and future emissions determines the chance that each pathway will result in the 1.5°C target being met.

Advances since the IPCC's special report in understanding key climate system factors now indicate that it will be even more difficult to limit warming to 1.5°C than previously assessed. These key factors include:

The sensitivity of the climate to changes in the amount of carbon dioxide in the atmosphere - How future CO_2 emissions relate to the chances of limiting warming to 1.5°C clearly requires an understanding of 'climate sensitivity'; how sensitive the global average temperature is to atmospheric CO_2[11]. One measure of this that is relevant to global warming projections is Equilibrium Climate Sensitivity (ECS). ECS is an estimate of the temperature change in response to a doubling of the amount of CO_2 in the atmosphere after a new equilibrium climate state has been reached. The IPCC's special report on warming of 1.5°C used the 2013 IPCC assessment that ECS was likely to be between 1.5 and 4.5°C[12]. However, a major international assessment of climate sensitivity by Sherwood et al. (2020) has since ruled out values at the low end of this range ECS[13] and has judged that the chance of ECS being less than 2.2°C is just 1-in-20. Even more recent assessments based on Earth's temperature change since the last Ice Age have ruled out the possibility of ECS values less than 2.4°C[14]. This means that some of the less ambitious emission reduction pathways for limiting global warming to 1.5°C presented by the IPCC's special report are less likely to meet this target than the report estimated.

How natural sinks and sources for carbon respond to a changing climate - Currently, about half of the carbon that humans emit is retained by the atmosphere. The rest is absorbed by carbon 'sinks' on the land and in the oceans. These carbon sinks, and the fraction of emitted carbon that is retained by the atmosphere, may change due to both increasing atmospheric CO_2 concentrations and climate change. There is evidence that some sinks on the land have been increasing due to effects such as forest regrowth and increasing plant photosynthesis in response to rising atmospheric CO_2 and/or the warming climate[15]. However, larger losses of carbon from the soil in individual years due to heatwaves and droughts have raised concerns about the vulnerability of land sinks to future climate changes[16,17]. Rising atmospheric CO_2 also leads to changes in the temperature and chemistry of the ocean that could result in less carbon uptake by ocean ecosystems[18]. Warming can also enhance sources of carbon by thawing permafrost, releasing carbon held frozen within the ground into the atmosphere. The vulnerability of carbon sinks and the behaviour of carbon sources is not fully understood and is an active area of research, but to achieve the 1.5°C target requires the balance between sinks and sources to be maintained. There is growing evidence to suggest that this is unlikely to occur. A report summarising ten important insights from climate science that emerged in 2020[19] highlights that deforestation in the tropics means that the carbon sink provided by land-based ecosystems will no longer be able to grow to keep pace with our carbon emissions. The report also highlights research that suggests carbon emissions from permafrost will likely be larger than anticipated by the IPCC's special report because climate models have not included processes that lead to abrupt thawing.

The warming effect of our emissions of greenhouse gases other than carbon dioxide - CO_2 is not the only greenhouse gas and important contributions to warming are made by our emissions of methane, nitrous oxide and a group of chemicals called CFCs. Large reductions in global emissions of non-CO_2 greenhouse gases are needed to limit global warming to 1.5°C. However, atmospheric concentrations of many important non-CO_2 greenhouse gases continue to increase. For example, a recent report by the UN Environment Programme noted that 'the atmospheric concentration of methane is increasing faster now than at any time since the 1980s' and that the 'Paris Agreement's 1.5°C target cannot be achieved at a reasonable cost without reducing methane emissions by 40–45 per cent by 2030'[20]. However, the report suggests that making such emissions cuts is perfectly feasible and cost effective. Since methane only remains in the atmosphere for around a decade on average, the effect on the amount of methane in the atmosphere, and the benefit to efforts to limiting warming to 1.5°C, would be immediate. However, because most of our enhancement of the greenhouse effect is due to our CO_2 emissions, most of which remain in the atmosphere for at least a few decades, this does not negate the need for immediate cuts in CO_2 emissions. Immediate cuts in CO_2 emissions will have an effect that lasts beyond the end of the century as most of the CO_2 we emit into the atmosphere in the next decade will contribute to global warming for decades to come.

The inertia of the climate system – The long lifetime of CO_2 in the atmosphere means that its climate warming effect responds to a reduction in CO_2 emissions only gradually, over many years. It also takes centuries to millennia for the Earth system to fully respond to changes in the greenhouse effect. This means that if atmospheric greenhouse gas concentrations were to stop increasing and remain constant from now on, it would take centuries to millennia for the warming of the planet to cease. We are uncertain about the degree of inertia in the climate system and this, compounded with our uncertainty in climate sensitivity, means that different models simulate a different amount of warming following such a stabilisation in greenhouse gas concentrations. However, a recent study[21] found that over 80% of the most recent (CMIP6) generation of global climate models ultimately warmed by more than 1.5°C above the pre-industrial temperature in simulations where increases in atmospheric greenhouse gas concentrations ceased in 2019. While some CMIP6 models may have high values of climate sensitivity[22], this result also held for earlier models. Palaeoclimate evidence also points to large inertia in the climate. Around 3 million years ago atmospheric carbon dioxide levels were similar to current levels, yet the Earth's climate was estimated to have been between 1.8°C to 3.6°C warmer than pre-industrial temperatures[23]. This reflects the temperature commitment that we would expect current levels of atmospheric CO_2 to have, given enough time (millennia) for the Earth system to fully adjust. These independent lines of evidence reinforce the need to urgently reduce, and not just stabilise, concentrations of greenhouse gases in the atmosphere if we are to meet the 1.5°C target.

The uncertainty associated with these science issues means that it is not possible to definitively answer whether the question of whether limiting global warming to 1.5°C still remains possible. However, overall, the latest climate science suggests that limiting warming to 1.5°C will be even more difficult than was assessed by the IPCC's special report in 2018. Given that global warming has already reached 1.2°C, significant and sustained cuts in global greenhouse gas emissions have not yet even begun to be achieved, and it is still doubtful whether carbon capture and storage will be possible at sufficient scale, it is extremely unlikely that limiting warming to 1.5°C is still practically achievable.

We should still aim to limit global warming to 1.5°C

Global warming of 1.5°C has extremely serious consequences. As was known in 2018, pursuing 'policies that are considered to be consistent with the 1.5°C aim will not completely remove the risk of global temperatures being much higher or of some regional extremes reaching dangerous levels for ecosystems and societies over the coming decades'[24]. However, the consequences of warming nearer 1.5°C are smaller and less damaging than those of warming of 2.0°C or more.

Not only is the likelihood of negative impacts from climate extremes less for a warming of 1.5°C[25] but the risk of triggering a tipping point in the climate system is also lower[26]. Tipping points are large, irreversible changes to the climate system, usually associated with catastrophic consequences[27]. Examples include the ultimate collapse of the West Antarctic Ice Sheet, leading to multiple metres of sea level rise, and a loss of Arctic permafrost, leading to massive releases of methane into the atmosphere and accelerated global warming. The precise amount of warming required to trigger tipping points is highly uncertain and the risk of triggering some tipping points may be mitigated if the temperature of the globe exceeds 1.5°C for only a short period of time[28]. However, recent research suggests that tipping points associated with irreversible loss of ice from the West Antarctic Ice Sheet, loss of summer sea ice in the Arctic and the destruction of coral reef ecosystems, including the Great Barrier Reef, could be triggered with a warming of around 1.5°C to 2°C above the preindustrial temperature[18,29].

Irrespective of tipping points, climate change adaptation efforts will be less costly and disruptive to society, and will stand a better chance of success, if warming can be limited to 1.5°C rather than 2°C or higher. We therefore in no way advocate for policies that forgo pursuing the ambition to limit global warming to 1.5°C, regardless of whether that target remains feasible or not. Aggressive cuts to greenhouse gas emissions that strive for 1.5°C will benefit adaptation, even if it transpires that global warming cannot be limited to this level.

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